Protecting the south-west of the Netherlands against flood using an adaptive design approach

TU Delft

Delft University of Technology

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Authors:
Xander Smits (4448111)
Rosalie Middendorp (4532562)
Kyriakos Kyrizakis (5164389)
Jean-Marie Hemel (4300661)
Naomi Dommerholt (4214781)
Sam Dijkstra (4360729)

Supervision:
dr. ing. Mark Voorendt
dr. ir. Jos Timmermans
dr. ir. Martine Rutten
dr. ir. Johannes Visser

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Summary

The Netherlands is world famous when it comes to coastal defence. The world is always changing, therefore the Netherlands, together with many countries, has to adapt constantly to the climate. This constant change means that in particular the coastline of the Netherlands requires extra attention because of the uncertainty of sea level rise. The Dutch coastline is protected by means of a static approach. However the intention for the future is to apply an adaptable design to better handle sea level rise. This report focuses on a method that uses a dynamic approach with the aim of keeping the Netherlands protected against rising sea levels that are uncertain. This dynamic approach consist of several pathways that each consist of different actions. With the help of evaluation-criteria, the pathways in the dynamic approach are evaluated. The outcome of this evaluation is described and recommendations for future research are given.

The report focuses on keeping the coastline of the south-west of the Netherlands protected against the uncertainty of the rising sea. This will be done with the help of a dynamic approach. First, an area analysis was carried out to find out what aspects should be given the most attention. After that, the method of DAPP is used to function as a dynamic approach. This Dynamic Adaptive Pathway Policy is then used to implement the different pathways in a structured way. These pathways are made up of different actions. These actions are existing plans presented by Deltares and they form a big list. Not all plans do function properly in order to function as a flood protection and so a selection method is used to extract the right plans out of this list. The requirements that are used to select the right plans have its main focus on protecting the hinterland against sea level rise, storm surge and wave load. The extracted plans that function as an action are implemented in the different pathways of the DAPP. To evaluate these pathways, evaluation-criteria are used in a Multi Criteria Analysis. These criteria are extracted from sources like a stakeholder analysis, old and new watermasters and a brainstorm session with the group members who act through their own accumulated expertise. The extracted criteria in combination with determined weighting factors are placed in a Multi Criteria Analysis after which the pathways have been assessed individually. This evaluation process led to some pathways being iterated to a different shape for the final design of the DAPP.

From the project can be concluded that the DAPP approach works well to combine different static plans into a comprehensive mitigation strategy. Secondly the evaluation criteria can be successfully derived from the old and new watermasters. The old watermasters already have one or more of their plans implemented. The new watermasters, are working on flood protection plans for the future in their daily life and have a lot of experience in the current engineering field. From the stakeholder analyses, the criteria can also be derived but than from the perspective of a variety of stakeholders. Thirdly, organizing criteria using a PESTLE (Political, Economic, Social, Technological, Environmental) and objectives tree has significant benefits for determining weighting factors. At last, it can be concluded that the main requirements used in this project are a good starting point, but they are only focused on reducing the flood risk (only technology). To select plans on a wider perspective(also Political, Economic, Social, Legal and Environmental), it is recommended to take a closer look to requirements from that perspectives. Advised is to consult experts in those fields to help with that.

Table of contents

1 Introduction

1.1 Climate change and the Netherlands

On the 1st of February 1953 the south-west of the Netherlands was flooded due to a south-western storm in combination with spring tide, this resulted in a loss of lives and infrastructure. The Netherlands reacted by building the now-famous Delta Works. The whole world watched and learned how they used the Delta Works to face the water. But now the Netherlands is facing new challenges due to climate change.

How are the Dutch going to deal with this new challenge? Timmermans et al. (2021) says that: "The Netherlands awaits a century of transformation, addressing our climate, biodiversity and resource crises. Transformative change requires the design of new futures that guide and empower transformation." Due to climate change, sea level will rise, storm surges will increase in occurrence and intensity, and the fluctuation in river discharges will increase as well. This makes the Netherlands prone to floods which calls for transformative change.

The coastal zone of the south-west of the Netherlands is especially prone to floods as the current protection system, 'de Deltawerken', will not be sufficient anymore. The design of a new protection system is influenced by many different factors which are unknown, like the sea level rise and the other points mentioned before. The complexity of climate change and uncertainties that come with predicting those changes are making it hard to design an appropriate defence system. For example how do you make sure that a defence system is not over-designed or under-designed? The sea level might rise with 3 meters by 2100 but it might also just be 0.3 meters, so how do you design for these uncertainties?

1.2 Learning from the past

Ronald Waterman (Appendix A) says that: 'Good plans have their roots in the past and point towards the future.' So step one in making a good design is looking back. A visit to the Delta Works gave a good insight into this past, the labour that was put into finalizing the Delta Works, the struggles they are still facing and the dimensions of the constructions.

Even though nobody wants a repeat of the events of 1953, the first issue that had to be faced was to have all the experts agree. This is one of the conditions to get to the realisation phase of any plan. This was taught by Henk Jan Verhagen (Appendix A), but getting experts on the same page is not the only requirement. There should also be an urgency in order to get plans realized. In the case of the Delta Works that was already in place due to the catastrophic event of the 1953 floods.

The visit to the Delta Works showed the difficulties that occur nowadays. Closing an entire estuary for example still influences the environment and wave climate within the estuary. And from the dimensions of the already constructed buildings it can be seen that it is not something that can be built in one day, so when do you start construction?

1.3 Looking to the future

Pointing towards the future has its obstacles due to the complexity and uncertainties. However, the Dutch society remains positive and came up with multiple new plans designed to protect the Netherlands. Projects such as Delta21, Haakse zeedijk, the sand engine, the Banjaard, Spaargaren sluices and Plan Waterman are looked into and main characteristics can be found in Appendix A, and will be analysed further in chapter 2.

At the symposium 'Protecting Delta Floods' of the University of Applied Science of Rotterdam and Stichting de Blauwe Lijn (2021) it stood out that a lot of cities, for example New York City, Taipei and Rio de Janeiro, face the same problem as the Netherlands does. The proposed student plans for these Delta cities were all inspired by existing plans, like the plans mentioned above. This made clear how static the current designs are.

1.4 Putting theory into practise

With roots in the past and pointing towards the future it is time to finally put this into practise. Brainstorming about plans to protect the flood prone south-west of the Netherlands resulted in a variety of plans. The first plan was creating a waterworld with flooding houses protected by wave breakers. The second plan was to relocate the harbour of Rotterdam further offshore and create building with city houses at the old harbour, while reinforcing the dikes. The third plan was inspired by build with nature and the 'Verlandingsplan'.These plans are depicted in Appendix B.3, but were those ideas new and innovative? And are they fit to protect the Netherlands against the effects of climate change?

2 Problem analysis

2.1 Issues with current plans

As explained in the previous chapter and in appendix A, there are many different plans to protect the Netherlands against the effects of climate change already. During the act of crafting a new plan and in reviewing the plans as done in appendix A, two main issues became apparent.

The first issue had to do with the evaluation of all the different plans. From the review in appendix A, it followed that each plan is crafted for a specific projection of the future, and that different plans focus on different aspects of mitigating the effects of climate change. The combination of these two factors means that it is exceedingly difficult to settle on evaluation criteria or requirements that encompass all aspects of a plan. The forming of criteria for future plans is further hindered by two future challenges. Firstly the public opinion on what is found to be important can change over time (Offermans, 2010). This makes working with stakeholders challenging. Secondly the method of evaluation can change. In the last thirty years there has already been a shift from purely technical thinking to a more integrated way of evaluation (van der Brugge et al., 2005), and it is unknown how this will further develop in the future.

The second issue that came up was the effectiveness of the currently proposed plans when the projected future conditions and the actual future conditions differ. Each plan is crafted with a specific projection of the future in mind, and it is optimized only for that projection. This is also called static planning. However, the specific effects of climate change as well as their extent bring a high level of uncertainty with them. The effectiveness of plans that do not account for this can be called into question when the actual future conditions turn out to be different than the projection (Kwakkel et al., 2012).

These two issues in turn led to two main questions that were further explored in the next sections: are these plans fit for dealing with the high level of uncertainty the Netherlands is facing, and how can these plans be evaluated?

2.2 Deep uncertainty

Building further on what was mentioned in the first section of this chapter, climate change leads to many uncertainties. This can also be called deep uncertainty which means that "we do not know what we do not know" (Marchau et al., 2019). The range of potential sea level rise and storm surges are some of the most important amongst these uncertainties, as these are the main drivers of forcing that coastal protections need to defend against. There are, however, many other uncertainties that influence which potential plans should be implemented. Some of these uncertainties can include socio-economic factors such as the change in land use, as well as other climate change related factors such as droughts or discharge from the rivers (Refsgaard et al., 2013). Mitigation strategies for the future should be able to deal with these different uncertainties in order to remain effective.

Most of the current proposed plans are static, meaning that they are optimized for one specific projection of the future. It has been shown that even for small changes in future projections, static plans rapidly lose their effectiveness (Kwakkel et al., 2012). One way of solving this issue in dealing with uncertainties is by robust planning, where plans are optimized over a range of different uncertainties. However, when looking further towards the future, with more deep uncertainty, a more effective way of creating plans is through increasing adaptivity or flexibility (Walker et al., 2002). Kwakkel states this is because when dealing with deep uncertainty there is also a chance of rare events happening (2016). These rare events are not accounted for with robust planning.

2.3 Adaptivity

As mentioned in the last section, a large issue with the current plans is that they are static. Most plans are heavily optimized for a single projection of the future, which implies major assumptions about how the future will look. If the future turns out differently, plans can quickly lose effectiveness (Dessai & van der Sluijs, 2007). Adaptive or dynamic plans are comprised of smaller actions, within a wider framework that will guide future actions when more information is known about the future (Albrechts, 2004). This leads to more effective, customized mitigation of the effects of climate change.

Additionally current plans can be hard to initiate due to the relatively hard lock-in of choices. This means that after a certain decision, it is very hard to switch to another choice. It is much tougher to get a project authorized and have funding secured with this lock-in, and with it the long term effects of the choice (Cuhls, 2019). Because in an adaptable design the solutions are broken down into smaller and more manageable choices based on what is needed at that moment, this can make it easier for a plan to be authorized and funded since governments have a tendency towards short-term thinking (Spurling, 2020). This also means less political urgency needs to be created in order for the government to start implementation (Cuhls, 2019). This is a beneficial change compared to the previous course of action, where works are started only after the occurrence of disasters. The floods of 1916 and 1953 are good examples of this. The flood of 1916, where nineteen people died and large economic damage was inflicted, led to the urgency needed for constructing the Afsluitdijk. This plan was designed by Cornelis Lely almost forty years prior, illustrating the hesitancy of governments to engage in large-scale projects with significant lock-in. In the second case, the flood of 1953, a disaster was again needed. This time it was to create the political urgency which would lead to the eventual fulfillment of the Deltaplan, a design that was suggested almost a decade before the flood.

2.4 Evaluation

Another main issue with the current plans is that there are no agreed-upon criteria for evaluating different plans. Initially there are two main features of current plans that lead to difficulty in establishing these evaluation criteria. On top of this, there are also two uncertainties connected to the field of future planning that further increase the difficulty of establishing them.

There are two main features of the current plans that lead to difficulties in settling on evaluation criteria. First of all, different plans focus on different aspects of mitigating climate change. As an example, mitigation strategies can include storm surge barriers, ecological interventions to protect biodiversity and land-use policies. It should be possible to evaluate all these different plans, meaning evaluation criteria have to be widely applicable. Secondly, planning is currently static (Dessai & van der Sluijs, 2007). This means that while a plan might be effective given a certain projection of the future, it quickly worsens as this projection turns out to be less accurate (Kwakkel et al., 2012).

Settling on evaluation criteria for plans is further hindered by two uncertainties in the field of future planning. First, public opinion on what is considered important changes throughout time (Offermans, 2010). This means that any evaluation criteria found now can turn out to be considered more or less important in the future. Second, the method of evaluation can change. In the last thirty years there has already been a shift from purely technical thinking to a more integrated way of evaluation (van der Brugge et al., 2005), and it is unknown how this will further develop in the future. If it were to further develop, aspects that were previously not considered could suddenly play a big role.

2.5 Problem statement

As identified above, many static plans have been proposed for mitigating the impacts of climate change. Due to the deep uncertainty inherent to climate change and future planning, however, these static plans are currently difficult to evaluate. These plans are also hard to implement, as much political urgency has to be created.

3 Objective

3.1 Main Objective

To solve the problem outlined in the previous section, in this report an evaluation method will be designed for current and future plans. This evaluation method will help policy-makers and other interested parties to assess the various plans.

3.2 Scope

In order to reach this main objective, it is important to have a clear scope. First and foremost, this helps to make sure the main objective is reached within the time allotted for this multi-disciplinary project. Additionally, having a clear scope further clarifies the contribution of this project and highlights which conditions the evaluation method is meant for. There are four main scoping points to keep in mind: the region for which the evaluation method is designed, the selection of plans in developing the evaluation method, the kind of plans the evaluation method is meant for, and lastly uncertainties in the field of future planning.

First of all, the evaluation method will initially be designed for the south-west delta of the Netherlands. This consists of the provinces Zeeland and Zuid-Holland, see figure 1. As this part is mainly coastal area, plans that focus against flooding from the sea will be our main focus. Plans that focus more on river discharge, for example, are thus not taken into account. Even though the designed method will be useful in other cases, this region will be the starting point. The decision for this area was based on the inspiration derived from the tour of the Delta Works and the brainstorm session, as was mentioned in chapter 1. This region has a rich history of engineering and has been deeply influenced by the old watermasters, meaning that there is something to build upon. The inclusion of the port of Rotterdam also means economic concerns are taken into account. These reasons lead to the belief that the south-west of the Netherlands can serve as a useful case study.

Figure 1: South-west Netherlands

Second of all, the aim of this report is to create and test an evaluation method as a proof of concept. This means it is not necessary to treat every single potential plan. This is why the amount of plans taken into account after the initial selection will be limited in order to fit the timeline for this project. The main requirement for the initial selection is that they protect against the main drivers of floods.

Third of all, the evaluation method developed is meant to be used with plans that deal with a lot of uncertainty. This means it might be less applicable for plans that do not deal with uncertainties. This is because important aspects such as adaptivity are not relevant in those cases.

Lastly, uncertainties in the field of future planning are not taken into account. As explained in the problem analysis of chapter 2, there are future uncertainties in the development of the evaluation method. These uncertainties consist of two things. First of all, which evaluation criteria are considered important can change through time. Second of all, the frameworks that are used for evaluation criteria can also change throughout time. For this project, it is assumed that this is not the case, and the evaluation method will remain stable. This is done to reduce complexity.

4 Approach and outline

This chapter starts with explaining the definitions used in the rest of the report. This is so that there cannot be any confusion about the terms used. The rest of the sections explain the approach and outline for the design of an evaluation method.

4.1 Definitions

- *Requirements* - That what is obligatory for a plan in order to be included in the design.
- *Criteria* - That will be used to evaluate designed pathways.
- *Action* - The selected plan(s) or parts of the design(s) that will be used in the DAPP approach.
- *Pathway* - The path actions make that will be used in the evaluation method.
- *Old watermaster* - Designer of already realised flood defence systems.
- *New watermaster* - Designer of future plans to be used in new flood defence systems.

4.2 Approach

In order to reach the objective of creating an evaluation method to help policy-makers and other interested parties with choosing an appropriate flood defence, different steps should be taken. The steps are illustrated in figure 2.

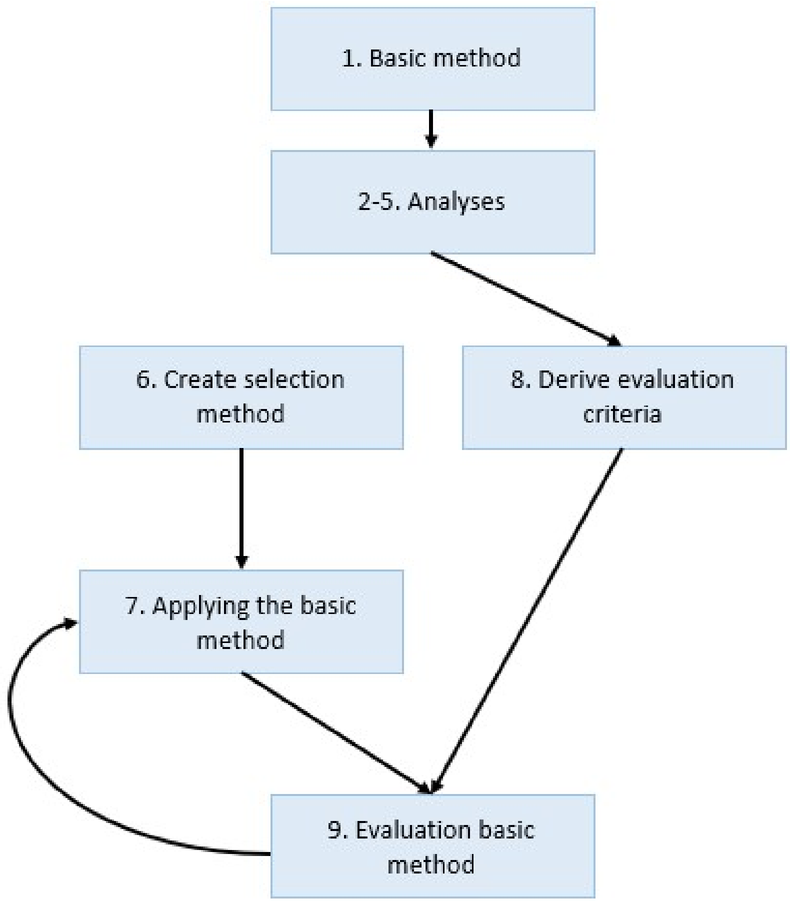

Figure 2: Approach

Step 1 - Finding a basic method for dealing with deep uncertainty
In chapter 5 a basic method for dealing with deep uncertainty will be selected. This basic method will be the basis of the evaluation method used to assess current and future plans.

Step 2 - Area Analysis
After finding a suitable basic method an area analysis will be conducted in the first part of chapter 6. The area analysis will be focusing on current protection measures in the south-west of the Netherlands, based on the scope mentioned in chapter 3.2. And look at the different aspect that (might) change and influence the flood risk defence system, mostly focusing on the effects of climate change.

Step 3 - Stakeholder Analysis
In this part of the chapter 6 the different stakeholders involved in the south-west of the Netherlands are analysed. From the stakeholder analysis, criteria will be extracted to evaluate pathways of a adaptable design in chapter 9.

Step 4 - Analysis of old and new watermasters
In the same chapter as the area analysis a more general historical analysis will be done, in which there will be a focus on the old watermasters and the new watermasters. From the expertise of these water masters, criteria will be extracted to evaluate pathways of a adaptable design in chapter 9. To be considered an old watermaster, he or she has to have created a plan to control the water that was also realised. This is not the case for the new watermasters. From this, lessons can be learned on how current protection measurements came into being.

Step 5 - PESTLE analysis
In the last part of chapter 6, the PESTLE analysis will be described to be used in chapter 9 to categorize the most important criteria. A PESTLE analysis is a way of studying all key external aspects that might influence a project. The letters of the acronym stand for Political, Economic, Social, Technological, Legal and Environmental factors. This will help to make sure no external factors are left out, and to organize the criteria that are extracted from the stakeholder analysis, the analysis of the old watermasters and the analysis of the new watermasters. After this, these now-ordered criteria will be used to evaluate the different pathways in chapter 9.

Step 6 - Creating a selection method
Chapter 7 focuses on a method that select feasible plans out of many plans available, for the purpose of this project the focus will be on the plans from Deltares (Deltares, 2021). This will be done with the help of a table of requirements that follow from the book Bed Bank and Shore protection (Schiereck, 2019) and a defined applicable range. After the selected plans pass these requirements and the applicable range, these plans will be implemented in the basic method to create an adaptable design.

Step 7 - Applying the basic method
Using the vulnerabilities and opportunities, chapter 8 applies the basic method found in chapter 5 to create different action plans for policy makers and other interested parties. These action plans will be presented in the form of pathways.

Step 8 - Derive evaluation criteria
The information that is provided in chapter 6 will form the basis for evaluation criteria that will be used to evaluate the pathways in chapter 9.These criteria are based on the old watermasters, the new watermasters, the stakeholder analysis and the brains storm session with the group. The PESTLE analysis will integrate all important characteristics that are found in chapter 6 and the brainstorm session. Important is to order the different criteria in a hierarchical way. With the help of an objective tree, weighting factors for these criteria will determined, to be used inside a Multi Criteria Analysis.

Step 9 - Evaluating the basic method
The pathways constructed in step 7 (chapter 8) will be evaluated with the help of the Multi Criteria Analysis determined in step 8, see chapter 9.

Step 10 - Reflection and discussion
Following the creation and the evaluation of the basic method a discussion part will be written regarding the validity of the results.

Step 11 - Conclusion and recommendations
Finally, this report will end with a section that brings together the most important findings and gives direction to future research.

5 Selecting a basic method for dealing with deep uncertainty

5.1 Motivation for adaptive planning

In the problem analysis it was found that one large issue with the current plans is that they are static. Static plans are less effective at mitigating impacts of climate change under deep uncertainty (Dessai & van der Sluijs, 2007). This is because static plans are optimized for a specific projection of the future. When the future turns out differently than this projection, they are quickly outperformed by other plans (Kwakkel et al., 2012).

This is why traditionally, rather than static planning, either robust planning or adaptive planning have been used rather than static planning in situations with high uncertainty. Robust plans are plans that are optimized over a range of different scenarios for some determined uncertainties. Adaptive or dynamic plans are comprised of smaller actions within a wider framework. This wider framework guides future actions, allowing decision makers to select actions when more information is known about the future (Albrechts, 2004).

When dealing deeply uncertain situations such as climate change where "we do not know what we do not know" (Marchau et al., 2019), the more effective way of creating plans between these two is adaptive planning (Walker et al., 2002). Kwakkel states this is because there is a high chance of rare events happening when dealing with deep uncertainty (2016). These rare events are not accounted for with robust planning, because the uncertainties as well as the range of future scenarios have been predetermined. On the other hand, adaptive planning creates a wider framework. This allows decision makers to pivot and adjust their strategy depending on newly arising situations. This leads to a customized, more effective mitigation of the impacts of climate change. While recently this dichotomy has shifted to a more synergetic approach where the benefits of both robust and adaptive planning are combined (Kwakkel et al., 2016), this approach is still in its infancy and is thus not taken into account.

5.2 Motivation for using a DAPP approach

The established way of adaptive planning for climate change adaptation is through the use of Dynamic Adaptive Policy Pathways (DAPP) (Marchau et al., 2019). This approach focuses less on trying to predict the future, and more on finding the conditions under which certain policies work (Haasnoot et al., 2013). This creates a broad framework, showing under which conditions each plan or action functions. The DAPP approach is a good fit for creating an evaluation method for four reasons.

First of all, current static plans can be incorporated within this approach. Once the conditions under which each plan functions are known, the current plans can be combined into a DAPP map. This means that all currently available knowledge is used to its fullest extent, as well as allowing policy makers to easily see the conditions required for each plan or action to function.

Secondly, using the DAPP methodology inherently means that the same evaluation criteria will be used for every plan, making comparison possible. This is important because evaluation does not happen in a vacuum. Without the ability to compare between plans, any evaluation done will hold less weight (Hsee, 2000).

Third of all, the created pathways in the DAPP map will allow all the different plans to be seen in the broader context of an integrated mitigation strategy against climate change. This allows policy makers to see how different plans link with each other and whether they enhance or diminish each other. Making these links concrete and visible grants policy makers the power to develop a more effective mitigation strategy by combining the right plans.

Lastly, one of the main benefits of using the DAPP approach is political, and inherent to adaptive planning: breaking down a long-term vision into short-term actions. As explained before, short-term thinking is pervasive in policy-making (Spurling, 2020). By using a DAPP approach, policy-makers do not have to commit to long-term plans, but instead only have to make a decision when an adaptation tipping point (ATP) is reached. This means lock-in is reduced, and less political urgency needs to be created before implementation of a plan can start (Cuhls, 2019).

5.3 Introduction of DAPP

As explained by Haasnoot et al. (2013), in the DAPP process a map with various pathways consisting of different actions is created. These various adaptation pathways relate to a main driver like SLR on the horizontal axis, as can be seen in figure 4. In this map, once an adaptation tipping point (ATP) is reached, the current policy or action has effectively finished and it is time to move to a new action.

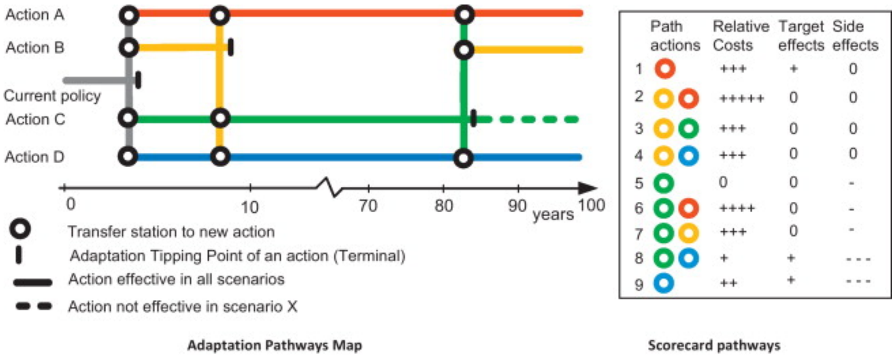

Figure 3: Example of an adaptation pathways map (Haasnoot et al., 2013)

After completion of the map, each unique way of moving from action to action is considered a pathway, with its own effects. These effects are reflected via a scorecard in order to show trade-offs between different pathways on the evaluation criteria. The benefit of having a complete map and scorecard without already cutting the worst scoring pathways is that it leaves room for decision-makers in the future to re-score the designed pathways based on future knowledge. As further explained in chapter 2, this relatively objective approach tries to negate the issues of changing public opinion through time (Offermans, 2010). It also leaves the option of creating a different method of evaluation or scorecard in the future open. This is beneficial since in the last 30 years we have already seen a shift from technical to integrated design, and it is uncertain how this will develop in the future (van der Brugge et al., 2005).

The full ten-step process that makes up the DAPP approach, from problem analysis to monitoring, is represented graphically in figure 4. The rest of the report will also refer to the steps described here. Steps two through six form the basis for the work done in chapter 8.

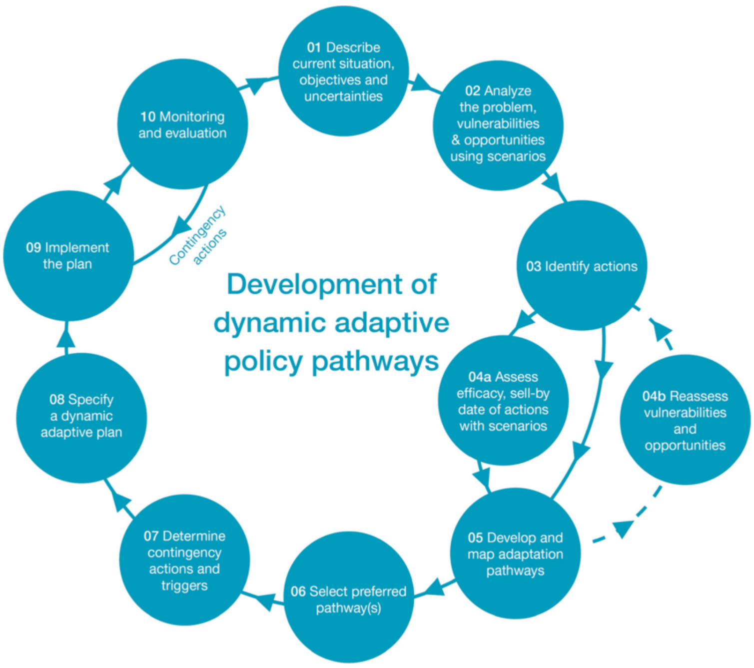

Figure 4: DAPP process (Haasnoot et al., 2013)

Currently in the DAPP process, the criteria used for evaluation of the created pathways are based on those that are deemed important by the designer of the map or by using expert judgment (Marchau et al., 2019). This lack of structure in finding evaluation could potentially lead to the absence of main evaluation criteria. The evaluation method developed in this report to assess different plans can perhaps also be used to assess the different pathways, strengthening the current approach.

5.4 The Deltares DAPP map for the south-west delta

Deltares has already started with the DAPP approach in developing a protection strategy for the Dutch coast. As this will report will partially build on this work, it is important to mention the main steps already taken. The first thing Deltares has done is collecting the most important of the current static protection plans for the Netherlands and categorizing them into four groups based on those initially proposed by the IPCC: extension into the sea, moving with the sea, open protection and closed protection (Deltares, 2021).

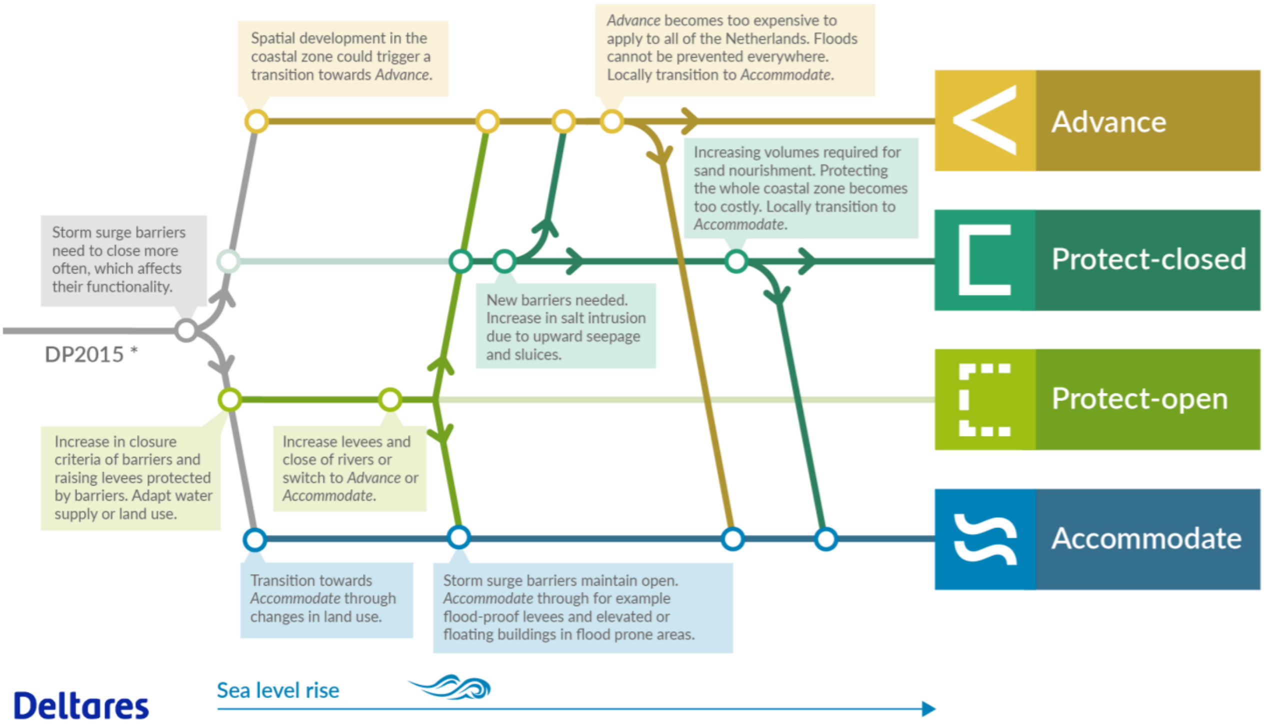

Figure 5: DAPP map for south-west of Netherlands (Haasnoot et al., 2019)

Next, Deltares has also already made a generic policy pathways map for these four main strategies, both for the Netherlands as a whole and for sub-regions. A graphical representation of such a map for the south-west delta of the Netherlands can be seen in figure 5. This map is currently still at a macro level, however. Currently it is still lacking specific adaptation tipping points, accompanying water levels and the specific plans that will be used.

5.5 Conclusion

Concluding, DAPP is a good approach to combine the current static plans into adaptive pathways. By combining the different plans, and seeing them in the context of an integrated climate change mitigation strategy, it makes it easier to evaluate all the different plans. Furthermore, DAPP breaks down long-term strategies into short-term decisions. This means less urgency is needed for governments to start with implementation, which is usually a problem. Lastly, DAPP is more focused on when certain policies would work, and less on trying to predict the future. This means that it already inherently solves problems such as shifting evaluation criteria or methods, because these can easily be adjusted.

6 Analysis of the south-west of the Netherlands

6.1 Introduction

This chapter describes the most important aspects of the area of focus. The aspects that are discussed are (relative) Sea Level Rise, the current Delta Works, coastal morphology and sediment transport, the hydraulic boundary conditions, the stakeholder analysis, the lessons from the old/new watermasters and the PESTLE analysis. In this way, this chapter gives an description of what is going on in the area and which aspects are important to be used as evaluation criteria in chapter 9 to evaluate pathways.

6.2 (Relative) Sea Level Rise

There is a lot of uncertainty around the magnitude of future sea level rise due to climate change. This in turn has an effect on the Dutch coastal protection strategy (Haasnoot et al., 2020). Uncertainties can come from a variety of places. Foster & Rohling (2013) addressed uncertainties in the relationship between CO2 and long-term sea level rise, which was found to be more than 9 meters above the present level with a 68% confidence. Bamber et al. (2019) addressed uncertainties that are inherent to deterministic modelling of ice sheets by using structured expert judgement. Their findings support the use of more than 2 meters of sea level rise by 2100 for planning purposes. Sudipta et al. (2021) mostly focused on the different research methodologies of the past 20 years and the uncertainties they are based on. The conclusion was that the risk of climate change is too high to be disregarded, but that the uncertainties, regarding sea level rise, will predominantly be dependent on future (unknown) societal decisions.

There is widespread agreement on the three mechanisms that influence the global sea level change:

- Tectonic and sedimentary processes
- Seawater density influenced by ocean temperature and/or salinity
- Thawing or freezing of glaciers and ice-caps

The first point being of little relevance as it insignificantly short compared to the human lifespan. The second point has a small influence and should not be ignored. The last point however has the biggest influence and therefore also has the most uncertainties (de Lange & Carter, 2014).

Garbe et al. (2020) says the same and states that the largest uncertainty is comprised of unknown amount of mass loss from the Antarctic Ice Sheets. They do not doubt that it will be the largest contributor to sea level rise. Pattyn & Morlighem (2020) predicts the same. All three authors agree that to reduce the uncertainty, new models and more data are needed.

Besides sea level rise, the delta areas are also influenced by coastal land subsidence, which occurs naturally. Coastal land subsidence combined with SLR is referred to as relative sea level rise (RSLR).

Deltares expects no major changes in the SLR and RSLR until 2035. Land subsidence is estimated to be 0.45 mm/year and the relative sea level rise is estimated to be 1.86 mm/year (van Gelderen & de Looff, 2020). This means that until 2035 the land subsidence is 25% of the RSLR (van Gelderen & de Looff, 2020). After 2035 it is expected that the land subsidence will slowly become less important, due to possible acceleration of the sea level rise (van Gelderen & de Looff, 2020). This is why in the rest of the report SLR will be used instead of RSLR, since the considered time scales mean land subsidence is less important.

The acceleration of SLR is unknown. For example in a low-likelihood, high impact story line the Global Mean Sea Level (GMSL) Rise can rise to 5 meters by 2150 (Arias et al., 2021). Taking into account all different uncertainties and predictions of emissions, different Representative Concentration Pathways (RCPs) are represented in the IPCC AR6 report (Ming et al., 2021). The mean of these predictions are visualized in figure 6.

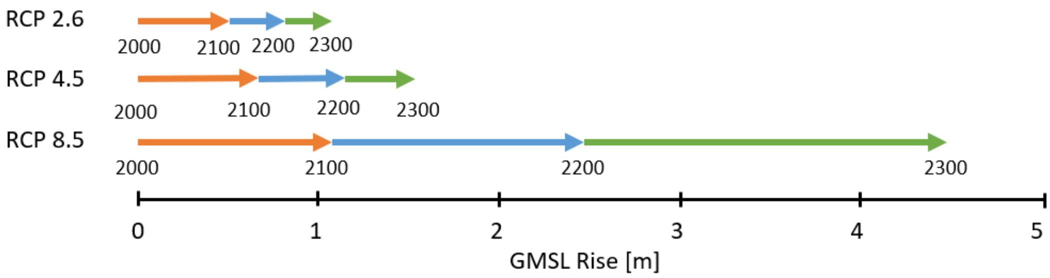

Figure 6: Time intervals with respect to the mean sea level rise for different RCP scenarios (Horton et al., 2020)

Figure 6 shows that the mean SLR in the most extreme predictions do not go over 5 meters in the next 300 years. Looking too far ahead can conflict with the efficiency of these new designs. This is tied closely to investment costs and the discount rate, as pointed out by Han Vrijling, see Appendix A. Furthermore, the uncertainties are too big and increase over time. However as the main driver of this project is to evaluate protection plans against flooding due to SLR, and most plans encountered are designed for a maximum of 5 m SLR, see AppendixD.4. Therefore 5 m is the maximum SLR used to select the plans, design the DAPP and evaluate the pathways.

6.3 The current Delta Works

The coastal protection system of the south-west of the Netherlands used to just consist of dikes. Before the implementation of the Delta Works, the estuary had an unhindered connection to the sea. Nature could take its course, and this resulted in an enormous amount of natural activity. The disadvantage of this open system is that during a storm a very large amount of dikes was exposed which increases the risk of failure. During the 1st of February in 1953, a heavy storm arrived in the south-west of the Netherlands in combination with a spring tide. Many dikes were not able to resist the force of the water which resulted in dike breaches. The water flowed into the hinterland leaving a trail of destruction and the deaths of 1836 people. Drastic changes were necessary in order to properly protect the Netherlands against future storms, which resulted in the Delta Works (Rijkswaterstaat, 2021a). The large-scale project has reduced the amount of coastline by 700km to 80 km which has a major impact on the safety of the hinterland (Rijkswaterstaat, 2021a). In figure 7 the flood defenses of the Delta Works are depicted.

Figure 7: Delta Works Rijkswaterstaat (2021a)

However, during the bus tour to the Delta Works, the experts explained that the Delta Works are not constructed regarding the current trends of sea level rise. According to 'Deltanieuws', the Easternschelt-barrier will close significantly more often after 2050 with a sea level rise of 35 centimeters or more. A sea level rise of 60 centimeters results in the barrier closing 10 times per year and 1.25 meters of sea level rise will close the barrier 100 times per year. This has a consequences for nature and shipping (Deltanieuws, 2017).

6.4 Coastal morphology and sediment transport

6.4.1 Influence Delta Works on the coastal morphology

Due to the construction of the Delta Works, the natural equilibrium of the estuary was changed. The smaller openings for in- and outflow of water resulted in a decrease of the amount of this flowing water. The huge trenches that conveyed this water flow will become less deep because less water flows in and out . To get more shallow trenches, nature creates a new equilibrium and therefore more sand is demanded. Nature has to take this sand from a source, and this is called sand hunger. Most of the sand is obtained from sources such as sediment which is transported from the south and from the sandbanks that are located in front of the coast(Bosboom & Stive, 2012).

The combination of waves and currents along the coast results in erosion. Besides the erosion, these same waves and currents create also a sediment transport that comes from the south and travels up along the coast of the Netherlands. This flow of sediment fills up the eroded parts that the waves washed away and so there is a natural equilibrium. The problem arises when the flow of sediment from the south is interrupted. In the case of the Delta Works, the problem started when the deep trenches adapt to the new equilibrium and therefore sand is needed for the trenches to become less deep. The sand from the sediment transport from the south will be used by nature to fill these deep trenches. This results in an interruption of this northwards going sediment transport at the location of these trenches. Due to this there is no sediment supply above the trenches, while the sand at this location will get washed away by the breaking waves and currents. This results in large coastal erosion above the trenches which is an unfavourable outcome(van Maldegem & van Pagee, 2005).

6.4.2 Influence changed morphology on ecology

After the construction of the Delta Works most of the tidal movement was restricted, resulting in a lack of fresh seawater in the estuaries. The result of this is that the water in the estuaries has a decreased amount of natural nutrients and oxygen. The forester of the Brouwersdam explained in the tour that the Delta Works in this way resulted in a decline of the once vibrant life. After some protests it was decided to open the revolving doors of the dams under no storm circumstances. This resulted in the water being able to flow in and out, and the estuary and her accompanying nature slowly recovered.

The sandbanks in front of the coast are partly located above the water level. The breaking waves on these sandbanks do ensure that small sea creatures such as shells and crabs come off the sandy bottom and wash ashore. This attracts many birds that eat those little sea creatures. Beside these birds, the sandbanks provide lots of space for seals that can rest without people approaching them too close. The result of the Delta Works is that the sandbanks will get eaten away and this sand will end in the trenches. When time passes, the animals that live on the sandbanks will get less and less living space.

6.4.3 Current yearly sediment transport directions

In figure 8, an overview is given of the main directions of the sediment transport in the south-west of the Netherlands as it is at the moment. In the figure, the net directions of annual sediment transport are given, so all seasons are included. This will give a good idea of how the sediment transport in the south-west of the Netherlands looks like. The main long-shore transport direction is northwards, which is caused by the dominant wind direction coming from the south-west. At Haringvliet and Grevelingen there is sediment coming from up-stream which is mainly exported to the sea. At the Westerschelde, sediment is imported. (Hesselink et al., 2003)

In general there is an shortage of sand at the Dutch coast, which is compensated by dredging or other safety measures. Without these measures the Dutch shoreline would retreat due to the rising sea level(see figure 9), this could end up in a flooded hinterland. In the future this shortage of sand in the Dutch coastal system will increase due to Sea Level Rise (de Winter, 2014).

Figure 8: Net yearly directions of the sediment transport (the small arrow indicates a small amount of transport)

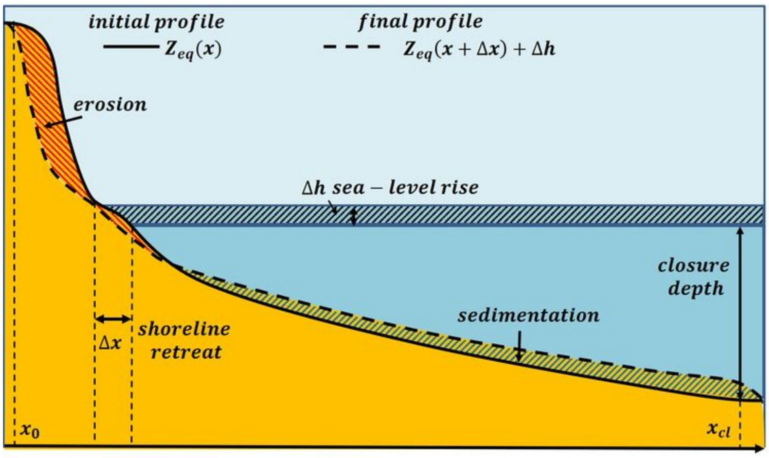

Figure 9: Bruuns rule (*Bruun rule for shoreface adaptation to sea-level rise*, n.d.)

6.5 Hydraulic boundary conditions

In this section the hydraulic boundary conditions of the south-west of the Netherlands are discussed. This is done to get an idea of the magnitude of the numbers which is needed to determine feasibility of the plans implemented in chapter 7.

6.5.1 Wave climate

For the wave climate, the magnitude of the extreme wave height, wave period and main direction of the waves are of importance for determining the feasibility of the implemented plans and will be described below.

Regarding extreme value predictions, Deltares predicted 1/10000-year wave heights using different distributions (Roscoe et al., 2010). This was implemented for the three offshore measuring stations in figure 10. The results for the predictions using the Conditional Weibull Distribution (CWD) can be found in table 1. As mentioned in the paper, this CWD method is mostly used for this kind of predictions. The extreme waves reach the Dutch shore from the north-west.

Table 1: Conditional Weibull Distribution (Roscoe et al., 2010)

	Hmo [m]	**Tm-1.0 [s]**	**Tp [s]**
EUR	7.77	11.30	13.14
LEG	7.72	11.18	13.39
SWB	6.77	10.72	12.56

Figure 10: Locations of the extreme wave height predictions (Roscoe et al., 2010)

A recent study states that the extreme wave height predictions (1/10.000 years) for 2071-2100 (using the SRES A1b scenario) do not differ significantly from those between 1961-1990 (de Winter, 2014). Thus, it is assumed that these extremes will not change in the future.

6.5.2 Current wind & storm statistics

In order to be aware of the magnitude, frequency and directions of the wind, the wind rose is used, see figure 11. The figure is the result of measurements taken from 1991 till 2020 at Vlissingen, which is a little fishing village in the south of Zeeland. From the figure it can be concluded that the dominant wind direction is from the south-west and the storms of 7 Beaufort (wind speeds larger than 50km/h) or more are coming from the south, west and south-west.

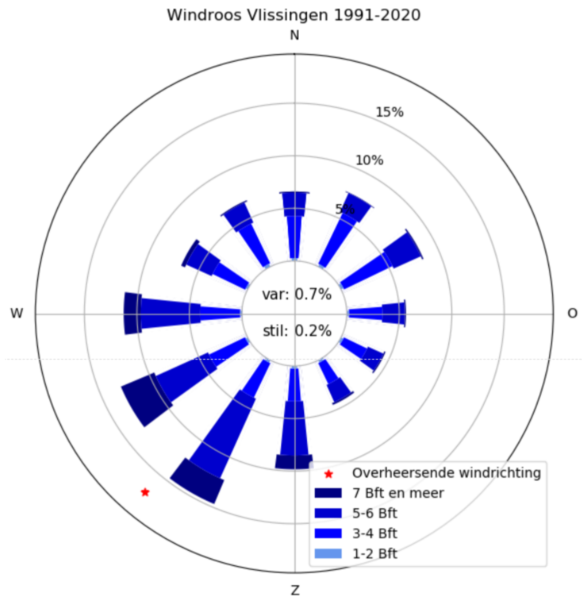

Figure 11: Wind rose of Vlissingen (KNMI, 2020)

There is a large inter-annual difference of these wind speeds, it is assumed that these will stay the same in the future, just as the magnitude of the extremes (up to 1/500 years)(de Winter, 2014).
Using historical model runs from 1950-2000 and comparing them with model runs from 2050-2100 (using the RCP4.5 and RCP 8.5 scenario's), it can be concluded that the magnitude of the (normative) extremes will not change in the future, just like the amount of wind coming from the north-west and north-north-west, which is the direction causing storm surges(de Winter, 2014).

6.5.3 Tide

The tide consists of many tidal constituents, however the lunar semidiurnal tide (M2-tide) is dominating at the Dutch coast. In figure 12 the time series of two months at Brouwerhavensche gate can be found. The location of the Brouwerhavensche gate can be found in figure 13. From the figure, the highest tidal water level is estimated to be NAP+1.92m and the lowest tidal water level is estimated to be NAP-1.28m

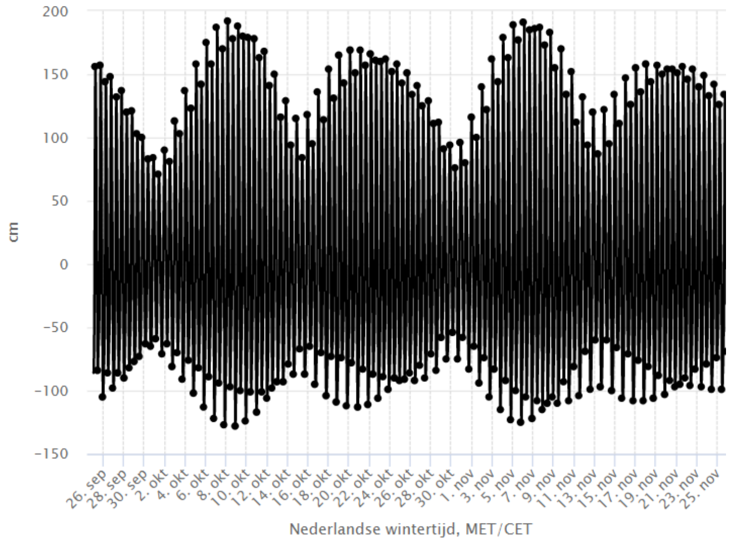

Figure 12: Tide at the south-west of the Netherlands (Rijkswaterstaat, 2021b)

Figure 13: Location of the tidal plot (Rijkswaterstaat, 2021b)

The tidal amplitude, phase and velocities depends non-linear on the the amount of SLR (Pickering et al., 2012). As the tide is very complex and the tidal behaviour depends on many factors, it is hard to predict the exact effect of SLR on the tide. However, what can be expected is that the SLR will increase the tidal range and velocities at the North Sea in the future(Bosboom & Stive, 2012).

6.6 Stakeholder Analysis

6.6.1 Stakeholders importance within traditional project problems

Traditionally, projects often deal with cost exceeding and time delays when trying to reach the proposed objectives due to uncertainties and other difficulties. This problem seems likely to continue in the future, since projects are becoming increasingly complicated and quite challenging external environmental conditions (like price fluctuation, tight legislative regulations) have been introduced(Sohi et al., 2016). Adding to project complications are important concerns raised among participants, which can be a huge obstacle in implementing the project if not taken into account. These kinds of projects demand a logical time frame to negotiate an adequate agreement between the project's interested parties. However, after a big round of discussions some parties might still be thinking of not accepted their concerns at all. That could possible drives to enormous disagreements and disputes with inevitably postponements. In order to avoid that, project organisation team establishes a sense of "mutual gains".

Despite the different viewpoints and expectations, all stakeholders will eventually search for common goals as well as finding jointly solutions. This tactic increases the possibilities of "win-win" situation among the parties and enhancing project's success at all. One of the things that probably should be done to achieve "mutual gains" is an open discussion session. By using that method, everyone is gathered around a table and non-discrimination in terms of listening understanding is taking place (that's the negative aspect of private negotiations between client – stakeholder). Simultaneously, running an open session allows all parties to discuss "face to face" and lying down their arguments. This will ultimately produce a collaborative decision-making (creating package deals instead of one-central decision) which in turn give an entrance to adherence through the project's indispensable deliverables (cost/time/performance) (Shmueli et al., 2008). Therefore, it's essential to establish a clear list of stakeholders and their expected values so as to drive through the creation of DAPP's evaluated criteria in chapter 9.

6.6.2 Stakeholders excluded issue

Even though a significant amount of effort is putting into learning how to work with stakeholders, this research is still at an early stage of development. Numerous definitions and techniques are currently used to attempt acceleration in understanding of both the motives and influence of stakeholders. The importance of clear definitions and tactics to use becomes even more clear when looking at previous unsuccessful collaborations and the disastrous results that come with it in terms of achieving the final deliverable and overall public and stakeholder satisfaction. For instance, the project of the Berlin Brandenburg Airport gives a perfect example of what happens when the opinions of stakeholders are ignored. The initial opening of the airport was postponed by over 2 decades and led to large public attention and even political intervention. The main obstacle which led to this failure was created by ignoring the airlines. Project developers did not take into account their demands, and thus proposed limited parking areas for smaller aircrafts. Because of that, huge disputes arose between project developers and airlines. The airlines disappointment was expressed in a large scale international airlines abandonment from the new airport (Kostka, 2016).

In that case, based on the above-mentioned parameters, the most sufficient definition including every aspect of the stakeholder world currently comes from a paper about major infrastructure in Hong Kong. In this paper, stakeholders are characterized as entities trying to influence and safeguard their incentives by attempting to set them as the first and unique priorities (Li et al., 2012). This paper also reports that the contributions and careful involvement of stakeholders throughout a project advance project knowledge and lead to the faster and more efficient reaching of project deliverables. Depending on that statement, project developers should collaborate and monitor potential future alterations in stakeholders' needs within the project's timescale.

6.6.3 Effective stakeholder incorporation

As stated in the previous section, in order to optimize a project plan and effectively implement it, close interaction with all the different stakeholders is necessary. In case of a flood protection project, stakeholders are required to get involved in the initial phase (called preliminary approach stage) so as to express their thoughts and feelings about possible opportunities and pitfalls throughout the project. However, an incorrect understanding of stakeholders' wants and needs could lead to unpredictably project postponements and a problematic situation that is difficult to reverse (Becchetti et al., 2011). A customized plan thus entails to be developed which encompasses everyone's sensitivities and attempts to reached them as much as possible.

Since project developers have to be knowledgeable of the stakeholders' considerations, they should launch a comprehensive strategic framework so as to incorporate stakeholders throughout the project. According to Eden & Ackermann (1998) a good technique to do this and distinguish different stakeholders is based on their power, attitude and interest. Regarding this, it is important to demonstrate clearly whose interest should be considered a priority. A well-oriented graph can depict each stakeholder's significance and societal status in accordance with their focal principles (such as safety, reliability, transparency etc.). These characteristics underpin parties fundamental essences and susceptible tipping points which serve an sophisticated final outcome. Therefore, the figure 14 below explains and classifies stakeholders regarding their power and interest status:

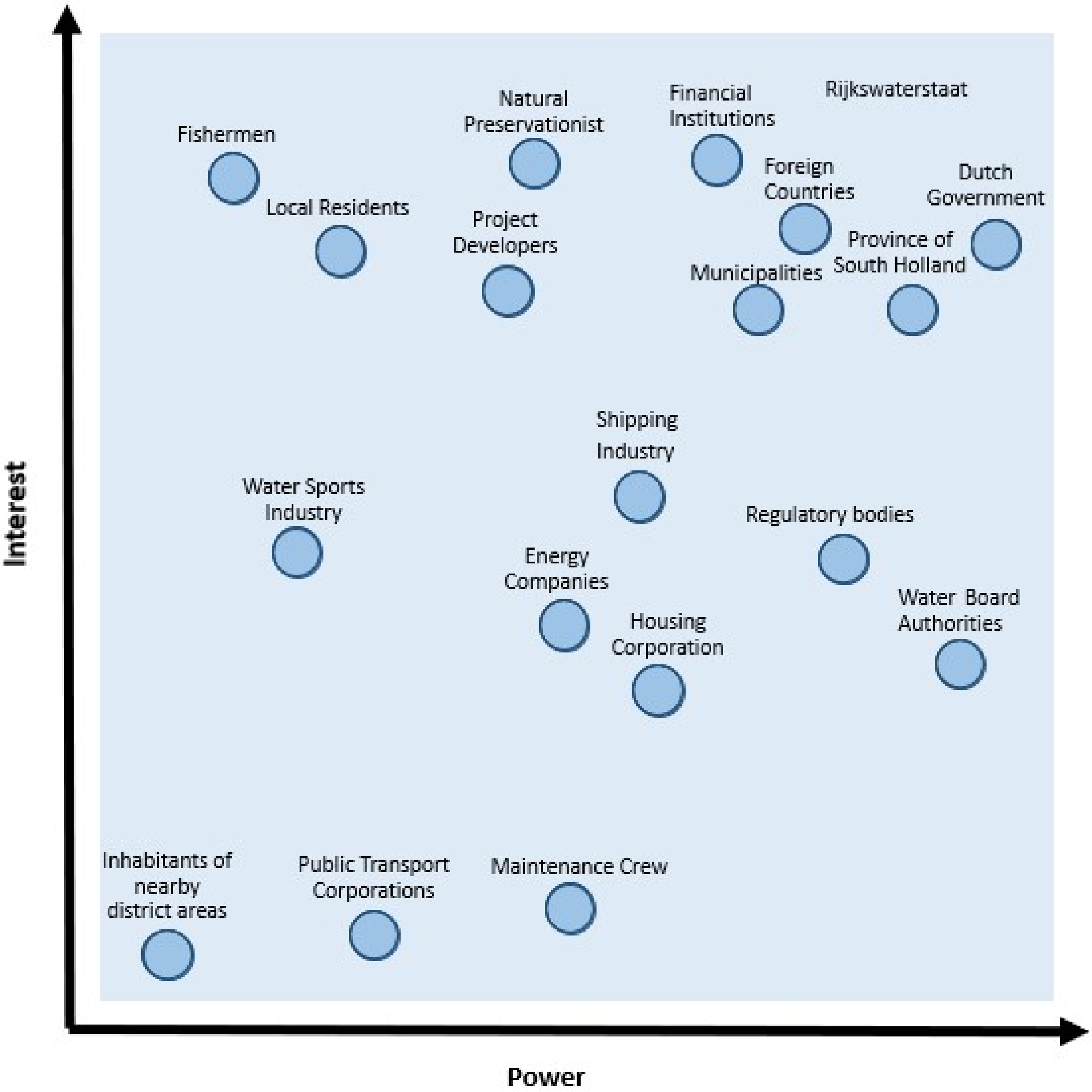

Figure 14: Power vs Interest

Based on the above graph, it's clearly illustrated that parties with really high power and interest are Rijkswaterstaat, Foreign Countries, Dutch Government ,Province of South Holland, Municipalities and on the other hand, Inhabitants of nearby district areas, Public Transport Corporation and Maintenance Crew are parties with low power and interest. Moreover, the above-mentioned stakeholders with high power and interest could be also determined as project's clients (contracting authorities) because they governed by public law and as well as initiate a project (mainly differentiation from other stakeholders) (Lopez Mino & Valcarcel Fernandez, 2014). In addition to, the power of each stakeholder could be separated in terms of the amount of financial, technical, or social resources as well as how easy it is to find these resources elsewhere. Doing this also shows whether a stakeholder is critical or not, meaning if a stakeholder is easily replaced by someone else (for instance, a government is a steady entity that everyone needs it in every project) . If a stakeholder indeed turns out to be critical, project developers should implement different strategies to satisfy them throughout the project's realization which is shown in Appendix C (figure 26).

The last step of a stakeholders analysis is to make an interaction map. This interaction map shows the indirect or direct stakeholders connection with each other based on their interest and expectation (multiple stakeholders might be interested in safety, for instance). This map graphically shows the most "vulnerable" areas (particularly "busiest" routes) and thus extra attention should be assigned to these areas for an ongoing project.

These project principles give a comprehensive review and categorization of stakeholders' values allocation. This turns out to be really helpful even if stakeholders distinction (leading to sort out view of who is critical or not based on the Power vs Interest graph) is taking place. As it was mentioned before, everyone has a freedom of speech and demands a mutual respect of their concerns (getting access to stakeholders values). Using that map, the project's developers could come up with effective ideas and solutions around a complicated subject that confused mostly stakeholders. The following figure 15 gives an visual demonstration of the interconnected project values, which are further elaborated upon below:

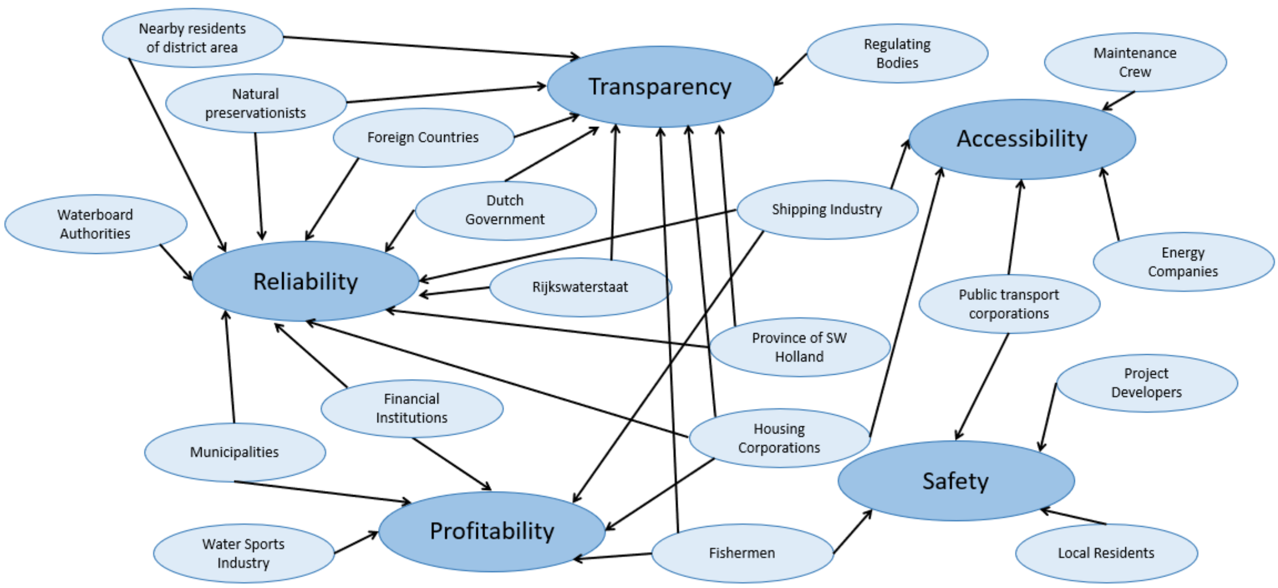

Figure 15: Stakeholders values

Given the fact that stakeholders values introduce a certain topic of further discussion, it's quite logical to give a detail explanation of those values. Thus, the upcoming points attempt to accurately pinpoint values definition:

Profitability:Social-economic status enhancement by creating earnings and revenues (Shipping Industry, Fishermen, Water Sports Industry, Municipalities, Housing Corporations)

Making humans richer than ever before, drives to certain commitment as well as ongoing acceptance of the project's beneficial characteristics. In case of protecting Netherlands from flood risk, a significant number of residents living around or actually in the project's site such as Fishermen, Water Sports Industries, Housing Corporations are explicitly influenced in a sense of economic prosperity. Additionally, one of the core issues that municipalities have to deal with is community's development (in sense of economic wealth). Once a project is proposed, municipalities need to make sure that society is fundamentally improving at a high rate. Lastly, Shipping Industry cares about inclusive and sustainable economic growth through its engagement of a large scale project (such as Netherlands flood protection)

Transparency:Open book situation with fair and honest development (Regulatory Bodies, Fishermen, Housing Corporations, Province of south-west Holland, Rijkswaterstaat, Dutch Government, Foreign Countries, Natural Preservationists, Inhabitants of nearby district areas)

That characteristic seems quite necessary in particular for Regulatory Bodies, administration authorities (Province of south-west Holland, Rijkswaterstaat, Dutch Government, Foreign Countries) and domestic groups (Fishermen, Housing Corporations, Inhabitants of nearby district areas). For example, it's really critical for Dutch government to undertake a clear demonstration of governmental plans especially for budgeting methods to efficiently allocate public money through different disciplines (such as the educational sector, health system, construction discipline, etc.). Particularly, in the construction sector those movements appear as slightly important in terms of eliminating public opposition and complying with legal authorization demands (some directives rules that need to match contractual relationships normally between clients – contractors). Additionally, an additional help to Province of south-west Holland and Rijkswaterstaat (since they develop close relations with Dutch Government) is given in order to continue their business activities without massive oppositions (mainly from Fishermen, Housing Corporations, Inhabitants of nearby district areas). In case of large scale projects (such as flood protection issues), Foreign Countries require a certain degree of trust in order to start negotiations for a project feasibility.

Safety:*Constant project implementation within elements robustness and integration (Project Developers, Public Transport Corporations, Fishermen, Local Residents)*

No matter of project's size or complexity, safety always included in the top primary concerns for successful result. According on that, in case of flood protective issue (looking into the Netherlands) there are plenty of parties that found safety as an indispensable factor. Since project developers is the basic executor of the project, they entail a certain degree of safety and security against potential dangerous circumstances (for instance overrated loads, incomplete/wrong drawings). Additionally, Local Residents, Fishermen and Public Transport Corporations have a considerably impact from project's safety as a significant amount of their works and accommodation depended on that principle (for instance Public Transport Corporations needs to execute their services around a safe structure, Fishermen looks through uninterrupted business activities and Local Residents living in safe environment)

Reliability:*Meeting project's demands (specifications) during a long-time technical lifespan (Dutch Government, Foreign Countries, Natural Preservationists, Housing Corporations, Province of south-west Holland, Rijkswaterstaat, Inhabitants of nearby district areas, Water Board Authorities, Municipalities, Shipping Industry, Financial Institutions)*

By introducing a large-scale project, it's necessary to emphasize how a project should be reliable and meet every specification or requirement. Since every detail is determined beforehand, project requires to show accuracy and effectiveness through its long-running schedule. More specifically, about protecting the Netherlands from flood risk, administration authorities (Dutch Government, Foreign Countries, Province of south-west Holland, Rijkswaterstaat, Water Board Authorities, Municipalities) needs to be aware of if that project "keep its promises" and stay reliable within a certain lifespan. That's a primary consideration from administration authorities due to the fact that large projects apparently have high investments and huge efforts from a wide range of parties. Additionally, many business companies (Shipping Industry, Financial Institutions, Housing Corporations) expressed a critical interest of project's reliability since they really care about their organisational feasibility. Moreover, Natural Preservationists attempts to keep environment as protected as possible and be assured that every intervention (such as a structure) could not be harmful at all. That relates to project's environmental analysis and how sensitive is too future alterations. Lastly, financial institutions provide a huge amount of money and thus every investment decision should be considered according to project's successful drivers (such as reliability).

Accessibility:*Non-blocking entrance within project's system boundaries (Shipping Industry, Public Transport Corporations, Maintenance Crew, Energy Companies)*

That principle has a profound meaning and its application ensures project success and long-term commitment (from interested parties). In case of flood protective issue (looking into the Netherlands), not only big entrepreneurship organisations (such as Shipping Industry) but also small entrepreneurship organisations (such as Public Transport Corporations, Maintenance Crew, Energy Companies) could look through equal treatment and free access. Since those companies attempt to remain sustainable in a challenging environment, a well-defined policy for unstoppable trade-off between different parts around globe should be established.

6.6.4 Stakeholders analysis findings

It can be concluded that a stakeholder analysis aids in an efficiently implementing project approach without disturbance or opposition. Therefore, the consequent steps were followed in this chapter:

- Explicitly identify stakeholders and distinguish them based on their resources and interest in the project.
- Recognize the critical actors and their contribution throughout the project principles.
- Establish the project's main values and principles, as well as by which stakeholders these principles are carried (since stakeholders engagement looks important, their 5 values could drive ultimately to DAPP evaluation criteria, in chapter 9).
- Establish strategies according to fairness and equality to refund critical stakeholders, helping to acquire commitment. This helps in implementation. Consequently, by using stakeholders values, the achieved outcome is broadly supported.

6.7 Old watermasters

Due to the massive risk of flooding in a country like the Netherlands, it is necessary to gather as much knowledge as possible. In the case of the Netherlands, there is a history of old watermasters producing flood protection plans which were implemented successfully throughout the years. Studying these old masters might lead to invaluable insights into what makes a good plan. Historical analysis in general can be a useful tool in planning to discover trends (Abbott & Adler, 1989). The lessons gathered from the old watermasters could provide the indispensable tools and techniques to effectively mitigate the uncertain impacts of climate change. From their successfully implemented plans, several important characteristics were derived. These characteristics will be used in chapter 9 to define the criteria that evaluate the pathways that are created in chapter 8. The following sections will explicate these essential characteristics considering flood mitigation plans as identified by the old watermasters. Some of these watermasters presented their plans and thoughts(see appendix A):

- Cornelis Lely - Zuiderzeewerken (presentation of Henk-Jan Verhagen)
- Johan van Veen - Deltaplan (presentation of Henk-Jan Verhagen)
- Marcel Stive - The Sand Engine
- Ronald Waterman - Plan Waterman building with nature

6.7.1 Essential characteristics from the old water masters

Urgency (Cornelis Lely)
Often urgency is needed before action is taken. An example is the Watersnoodramp in 1953. After this tragedy in the south-west of the Netherlands, the government realised this shouldn't happen anymore and so the search to a solution was accelerated. This resulted in the implementation of the Deltaplan that had been ready for years.

Small adaptations at a time (Ronald Waterman)
Small adaptation of a plan a time results in smooth implementation in the area. This results in that the surrounding like nature can adapt to the changes that do occur due to implemented plan.

Good financial basis (Cornelis Lely)
A good financial basis is of importance because when the government has strong financial possibilities, the chance that a high quality-plan will be implemented is increasing.

Finding publicity (Johan van Veen)
The power of the public can not be underestimated. Seeking out and involving the public in an urgent social issue such as protecting the Dutch coast is important when it comes to speed of implementation in the area.

Good technical basis (Johan van Veen)
When a plan is worked out in detail and the technical aspects have a good coverage, the chance that a plan is implemented is increasing. When technically deeper substantive questions arise, it is a good sign if all these questions are followed by a well-founded argument.

Experts should fully agree (Cornelis Lely)
An agreement between different experts on the performance and quality of the plan to be implemented in the area is of great importance. This group can then function as one and in this way give a joint opinion so that current and future problems will be reduced as much and good as possible.

Coherence between plans (Johan van Veen)
When there is a good coherence between plans, overall performance will increase. This performance can be divided in different aspects like; implementing different plans sequentially, good connection between plans that are implemented at the same time, and the overall performance of the plan do reduce the problems in the affected area.

Adhere to laws now and in the future (Cornelis Lely)
The world is constantly changing. This, of course, also applies to the laws used to keep society running. Therefore it is of importance to pay attention to possible changes when it comes to laws being applied to implemented plans in the future.

Multi-functional use of nature, building with nature, and create new nature (use of eco-friendly methods)(Marcel Stive, Ronald Waterman)
When the aspect nature is implemented in plans, it mostly results in a long-term stable collaboration between what is good for people and nature. When nature is not harmed but is used within the project, it will of course give something back in a positive sense. However crazy the world has changed, a fact is that nature has always adapted to a new equilibrium. Knowing that the sea level is rising, it is therefore also wise to realize that the use of nature has double benefits when it comes to achieving this new equilibrium. The first benefit is that in the case of proper use, the hinterland is not getting flooded. The second benefit is that nature can develop well and so that biodiversity can develop positively across the whole country.

6.8 New watermasters

In the future, the current flood protection system at the south-west of the Netherlands gets outdated, this in combination with the rising sea level causes floods when nothing happens. Therefore the new watermasters, in this report defined as "Designer of new plans to be used in new flood defence systems" in chapter 4, thought of different plans and methods to deal with this problem. Some of these watermasters presented their plans and thoughts(see appendix A):

- Leo van Gelder - Inlet sand dunes / plan Spaargaren/sluices
- Idco Duijnhouwer - de Banjaard
- Han Vrijling - SLR
- Dick Butijn Wil Born - Haakse Zeedijk
- Jos Timmermans - Transform by design

The presenters have many years of experience in the field and are working on the current problems in their daily working life. This makes the presenters a good source for gathering lessons, from these lessons important characteristics are derived. This subsection will explicate these essential characteristics considering flood mitigation plans as identified by the before mentioned new watermasters.

To do so, characteristics that are already mentioned under the previous subsection about old watermasters are not taken into account. So things like: creating urgency, a good technical basis, phaseability, building with nature, etc. are not taken into account, but were also things that came back as important characteristics in the presentations of the new watermasters.

Furthermore, the information in this subsection will in chapter 9 be used to define evaluation criteria. This is taken into account while writing down the characteristics.

6.8.1 Essential characteristics from the new watermasters

Cheap by using nature (Leo van Gelder)
In his plan Leo van Gelder uses man made inlets in dunes to naturally reinforce the dunes. In this way you let nature do most of the work, which saves money if you compare it to instance reinforcing the dunes yearly with beach nourishments.

Salt-water intrusion/fresh (drinking) water storage (Leo van Gelder, Idco Duijnhouwer, Dick Butijn and Will Born)
In the plans of most of the new watermasters, a solution for salt- water intrusion is taken into account. While this is already a common known problem, the special attention of the new watermasters confirms the importancy. Salt-water intrusion causes mainly agricultural damage and contamination of the fresh drinking water.

Creating economic opportunities (Dick Butijn and Will Borm)
While in more presentations the creation of economic opportunities was mentioned, especially the plan of Dick Butijn and Will Born contained a lot of economic opportunities. They created space for floating cities, an airport in the sea, an harbour extension. this can all be seen as economic opportunities.

Investment costs and discount rate (Han Vrijling)
The costs is something that came back in every presentation. There are plans like for instance the plan of Leo van Gelder(creating inlets in dunes). This plan is cheap as nature does most of the work, also no/little maintenance is needed. On the other hand you have the plan of Dick Butijn and Will Born (Haakse seadike). This plan has very large investment and maintenance costs.

Tied closely to investment costs is the discount rate, as pointed out by Han Vrijling. This discount rate is used to take into account the depreciating value of infrastructure over time. It states that the same amount of money is less valuable in the future due to inflation. This means that whenever possible, infrastructure investments should be pushed to the future. This helps to counter the depreciation.

Operational costs and maintenance costs (Dick Butijn and Will Borm)
The operational costs is something that came forward especially during the presentation of Dick Buijn and Will Borm. In their plan they use high pumping capacity, which needs a high amount of energy and thus has high operational costs.

Coherence between plans within pathway (Jos Timmermans and Dick Butijn and Will Borm)
When you think of the design of an adaptable pathway, it is important that there is a smooth transition between different plans. Which was Learned especially from Jos Timmermans, Dick Butijn and Will Borm. If this is not the case, there is an possibility that some of the plans in a pathway are realised too late. This can result in no proper protection against the seawater and thus can cause floods.

Functional lifetime plans matches properly with actual SLR(Jos Timmermans and Dick Butijn and Will Borm)
Plan Haakse seadike of Dick Butijn and will Born is a good example, this plan is build up of phases. A new phase is only realised when a certain seawater level is reached. In that way you prevent over dimensioning your plan and your plan is coherent with the actual seawater level.

6.9 PESTLE Model

These days, it's widely accepted that there is a necessity for dynamic adaptivity and thus an additional pressure is put on the decision-making process. Models are used to quantify and demonstrate in qualitative figures how a project could be settled down and explores different perspectives and features to cope with a deeply uncertain environment (Bosch-Rekveldt et al., 2011). A model that is utilized broadly for organizational analysis is called PESTLE. This model examines different "external factors" that are comprised into 6 basic categories: Political, Environmental, Social, Technological, Legal and Economic. The analysis of these factors shows how an organisation could extract vulnerabilities and opportunities in accordance with future investment decisions. Therefore, it appears necessary to give a detail description about PESTLE model factors and how their contribution via organisation's success is realized. The following points demonstrate an explicit view of those factors:

Political
The political environment imposes critical features of how a country should go ahead through a significant number of years (for instance in democratic nation, every 4 years elections are taken place). An interrelated connection between political stage and different societal disciplines (for instance education sector, health system, industrial field, legislative system) perhaps indicates slightly productivity and sustainability issues. In other

words, any kind of instability and turbulence have a major influence within an organization outlook and future business uncertainty is concerned at a high rate. For instance, the economic recession in 2009 introduced a massive alterations in the political decision around the globe (Salamon et al., 2009). That critical situation was concerned as a start of several adjustments and amendments in the sizable organisations business model. That sudden change emphasizes how politics situation is deemed so essential in order to appraise projects (either static or adaptable) worthiness (looking into a dynamic uncertain environment).

Economic
Mostly, economic factors play a prominent role via an organizational structure. According to them, numerous investment decisions are deeply considered whether or not project's economic successfulness could be accomplished. A certain kind of instruments and methods, such as Net Present Value (NPV), Cost-Benefit Analysis (CBA) are broadly applied in order to assess if project's feasibility remains acceptable within a highly uncertain future. Those methods are taking seriously some indispensable parameters which influence the economic consistency of a project. These parameters are inflation rate, recession and tax regulations. By including those factors, a more concise picture of project's will be established and effective criteria will set up an optimum plans evaluation process.

Social
A social perspective implicates an unique strategic mechanism in order to guide successfully an organization. Our world is comprised of some certain principles, such as values, norms, virtues that emphasize the importance of equality and fair treatment among different entities. In that case, beliefs, expectations and serious doubts should be expressed from every interest party without sense of fear or rejection. That kind of "openness" brings an optimum way of organisations project's assessment by looking clearly which plans should be executed or not. In other words, evaluation process would be held on terms of equality and non-discrimination(Van de Poel & Royakkers, 2011).

Technological
Technological development is changing so rapidly and plenty of entrepreneurs have to keep in contact with latest improvements in order to be sure for an ongoing future business progress. For every organization that issue remains quite necessary and demands a certain time and money (from organization viewpoint) to be attributed on that. That ensures relative highly fleet advancement with state of the art equipment which provides a remarkable company's deployment itself and active participation through market environment. In addition, since technological developments have a predominant role in project's execution stage, their importance is presented through the plans evaluation process as well. That leads to an efficient implementation with sophisticated outcome.

Legal
Wherever an organization sets its own business activities, it's essential to follow up with laws and regulations that a nation included within each institutional framework. According to that, every project has to steer with certain guidelines and instructions in order to acquire a legal positional acceptance and mitigating any kind of disputes and conflicts particularly with land owners. For instance, a well-defined example is the aesthetic criterion that a municipality claims as an important factor for a structure to get the environmental permit. Explicit rules are established so as to ensure a proper commitment (from project developers) through the aesthetic surroundings harmonization. In other words, legal adherence will definitely contributes to efficient plans assessment based on exclusive criteria (no matter how static or flexibly a plan is) (Hobma & Jong, 2016).

Environmental
Over the years, planet is incrementally growing and human industrial activities introduce an additional concern about natural resources over-consumption. That leads to profound atmospheric pollution and catastrophic results in natural ecosystem. In order to mitigate those slightly devastating effects, every organization should induce certain eco-friendly tactics (such as lower raw materials utilization and extraction) to rehabilitate natural environment and ensuring a sustainable ecosystem for future generations. In that case, organization's reputation will be rising and environmental damage will be limited at all. Additionally, in such a way of thinking an explicit environmental alignment would be implemented in accordance with exclusive techniques to appraise plans validity and effectiveness (Bradshaw & Brook, 2014).

According to Yüksel (2012), "PESTLE model is mainly implemented to provide a general idea about macro environmental affairs, such as environmental protection/health and their influence through company's status quo". However, it has already been mentioned before that apart from environmental feature there are also some additional factors (political, social, economic, technological and legal) which have similar importance and presumably exert a profound alteration though organization's main drivers. Around on that, a PESTLE model would be applied in case of transforming the Netherlands into a flood protective country as a "validation" tool to ensure that every critical aspect from the old/new water master, stakeholder analysis and brainstorm session is properly included and nothing is missing (contributing to project's optimum execution stage). In sense of its application, indispensable criteria would be ultimately found out and evaluation process could be applied in DAPP model (chapter 9)

More specifically, based on the above-mentioned information it's absolutely necessary to initially matching project's stakeholders with the PESTLE model in order to produce a sort out integration between the most vital traits in sense of project's success (stakeholders- PESTLE factors). For that reason, the given manual table illustrates profoundly in which category each stakeholders is assigned itself via the project realization:

Stakeholders	Political	Economical	Social	Technological	Legal	Environmental
Municipalities	✓	✓	✓			
Regulatory bodies					✓	
Maintenance Crew				✓		
Energy companies		✓		✓		
Project developers			✓	✓		
Housing corporation		✓			✓	
Local Residents			✓			
Public transport Corporations				✓		
Water Sports Industry		✓				
Shipping Industry		✓				
Water Board Authorities	✓					
Dutch Government	✓		✓			
Inhabitants of nearby district areas		✓	✓			
Fishermen		✓	✓			✓
Natural preservationists						✓
Rijkswaterstaat	✓					
Foreign Countries	✓					
Financial Institutions		✓				
Province of SW Holland	✓	✓	✓			

Figure 16: Stakeholders integration in PESTLE model

Based on the above table, it's quite understandable that every factor has a critical contribution through stakeholders identification and thus any kind of information is totally incorporated.

6.10 Conclusion

Since floods are presumed as a vital problem, the members of scientific community attempt to reduce and handle it. Technological development and broad knowledge are becoming tools of humans in order to tackle effectively floods over the years. However, it's necessary to embody every detail (for example morphological information, statistical analysis) and interest parties (like stakeholders, old/new watermasters) into an integrated framework analysis so as to achieve not only problem awareness (related to repercussions) but also public commitment and dedication to the final objective (measures for flood protective land). Consequently, having included masters (old and new) future concerns, stakeholders values and brainstorm sessions, an interesting and most importantly exclusive criteria extraction will take place in order to evaluate precisely future plans (chapter 9).

7 Development and implementation of the selection method

7.1 Introduction

This chapter describes the development of the selection method to select plans that are suitable for the DAPP as actions. The developed selection method first selects on main requirements which are based on functional characteristics, after which the remaining plans are given an indication of the range they are applicable for in the DAPP. In this way the plans can be dynamically added in the DAPP.

Note: In order to keep the focus on the main requirements and applicability of the plans for the DAPP. The requirements are derived from the book "Introduction to Bed, bank and shore protection" (Schiereck, 2019). The lessons learned from the old watermasters, the new watermasters and Stakeholders are not used in this chapter. However in retrospect this would have been a good way to derive the requirements. This is further discussed in chapter 10.

7.2 Development of the selection method

7.2.1 Main requirements of the selection method

The main goal is to protect the south-west of Netherlands against floods, therefore the plans suitable for the DAPP should protect against the main drivers of flood, to be able to act as an action in the DAPP. As coastal protection is the main concern of this area, the most important (extreme) loads on a coastal structure are taken into account as main requirements. These requirements were found by consulting "Introduction to Bed, bank and shore protection" (Schiereck, 2019).

In the coastal area the most important loads are wave load and hydro-static load. The hydro-static load depends on the water level, therefore can be divided into SLR, storm surge and the tide. As concluded in chapter 6.5 the tides' extremes are considered constant, therefore do not act as a requirement. Wind loads are also less relevant for the design of coastal protection structures (Schiereck, 2019), and are also considered constant, see chapter 6.5, therefore do not act as a requirement. This results in the following main requirements which are aimed at reducing the flood risk: SLR, storm surge and wave load.

Requirement 1: SLR
The increasing hydro-static load that is partly caused by SLR is an essential requirement for plans to act as an action in the DAPP as some of the plans only dampening the incoming wave height, but do not protect against the rising sea level.

Requirement 2: Storm surge
The hydro-static load that is partly caused by the temporary load storm surge is an essential requirement for plans to act as an action in the DAPP.

Requirement 3: Wave load
It is important that plans resists wave loads as well, as otherwise plans cannot solely act as an action in the DAPP as the waves should be reduced in height and length.

If a plan cannot meet these main structural requirements, this does not mean that the plan is useless. For instance when a plan is solely useful for damping out the energy of the waves (reducing the height and/or wave length), it can be used as an addition to the plans that do meet the main requirements. For this research this would become too complex and therefore only the plans that can protect against the main loads are considered.

7.2.2 The applicable range of the selection method

The plans remaining after selection based on the main requirements are given an indication of the range they are applicable for in the DAPP. The applicability range is indicated for the construction time, functional life time and SLR resistance as these aspects can be indicated in DAPP as they are based on time and/or SLR resistance.

Applicability range 1: Construction time
This is the time it takes to construct the plan.

Applicability range 2: Functional lifetime
This is the time that the construction will last.

Applicability range 3: SLR resistance
This is the sea level rise the plan can resist.

7.3 Implementation of the selection method

7.3.1 Selection of plans

The plans that are used as an example to demonstrate the selection method are found in a collection on the Deltares platform. Deltares is a Dutch non-profit independent research institute of water and has an open source policy. Their Deltares wiki has an updated overview of all the plans related to adaptation to SLR. The plans are divided into the four strategies determined by the IPCC (Deltares, 2021):

1. **Protected closed** (beschermen gesloten): The Netherlands will be permanently closed from the sea and the rivers have to be pumped out to the North sea.
2. **Protected open** (beschermen open): Keep the current adaption method with rivers staying in direct connection with the sea while the Netherlands heightens the dikes.
3. **Seawards** (zeewaarts): Moving the coastline seawards to improve safety and create space.
4. **Move with the sea** (meebewegen): controlled abandonment of vulnerable areas while protecting areas with a high economic value.

As mentioned in the scope (Chapter 3.2) the plans are chosen as a proof of concept. To get a good representation of the all the current plans at the Deltares wiki five plans are chosen from each of the four strategies. As having a variety of the plans is beneficial for the DAPP since it increases the adaptivity. These plans are rated to create and test the selection method. For each of the 20 plans a short description will be given in Appendix D.4.

7.3.2 Application of the selection method

The 20 plans are rated on the requirements and the applicable range. The way of rating is explained below.

Requirements:
The main requirements are rated by looking if they can protect against these 3 most important hydraulic loads or not. Plans in blue satisfy the main requirements.

- **SLR:** When the plan is SLR resistant, the plan will be marked with ✓, otherwise ✗.
- **Storm surge:**When the plan is storm surge resistant, the plan will be marked with ✓, otherwise ✗.
- **Wave load:** When the plan is wave load resistant, the plan will be marked with ✓, otherwise ✗.

Applicable range:
The applicable ranges are rated looking at the time and the level of SLR resistance per plan. These aspects are scaled as there is no or little information available of these aspects of the plans. Depending on the aspect the range differs. Having a different range of these aspects help to improve the adaptability of the pathways.

- **Construction time:** This is the time it takes to execute the plan. This will be scaled from 0 to 100 years, as the construction time is rarely longer than 100 years. Also construction times longer than 100 years are impractical, thus not useful.
- **Functional life time:** This is the time the structure will last. To be on the safe side this is scaled from 0 to 100 years. This is a point of discussion as it is of course an option to extend the life time if the construction is well maintained and renovated in time.
- **SLR resistance:** As the sea level rise is not expected to rise more than 5 meter in the coming 300 years, see chapter 6.2, the plans are scaled from 0 to 5 meter SLR.

For most of plans it is difficult to determine these applicable ranges in detail as there is no or little information available from the founders of the plans. For the purpose of this project the applicable ranges are determined using estimated guessing. A detailed explanation of the choices made regarding the main requirements and applicable range can be found in Appendix D.4. The conclusion from this detailed explanation results in the overview given in figure 17

	Main requirements			Applicability range		
Policies/ Main Hydraulic criteria	Sea Level Rise (SLR)	Storm Surge	Wave Load	Construction Time (years) [1-100]	Functional Lifetime (years) [1-100]	Sea level rise resistance (m) [0-5]
1. Protected closed - Beschermen gesloten						
A Plan Emergo	✗	✗	✓	-	-	-
B Vestuiving in de duinen	✓	✓	✓	1	10	0.5
C Kunstriffen	✗	✗	✓	-	-	-
D Deltadijk / Terpdijk / Klimaatdijk	✓	✓	✓	50	100	1-5
E Plan Sluizen	✓	✓	✓	10	100	0.85
2. Protected open - Beschermen open						
F Haakse Zeedijk	✓	✓	✓	40	100	5
G Dijkstad	✓	✓	✓	25	75	1-3
H Ecobeach	✓	✓	✓	1	100	3-5
I Dynamisch handhaven kustlijn en kustfundament	✓	✓	✓	1	50*	1
J Eiland voor één seizoen	✗	✗	✓	-	-	-
3. Advance - Zeewaarts						
K Verbrede Kust	✓	✓	✓	25	50*	3-5
L Plan Waterman	✓	✓	✓	25	50*	3-5
M Geleidelijk aangroei Hollandse en Zeeuwse kust	✓	✓	✓	25	50*	3-5
N Evoluerende Blauwe Eilanden	✓	✗	✗	-	-	-
O Brede kuststrook	✓	✓	✓	25	100	4
4. Accommodate - Meebewegen						
P Getijdenstad	✓	✓	✓	100	100	5
Q Terpen van baggerspecie	✓	✓	-	-	-	-
R Drijvende Stad	✓	✗	✗	-	-	-
S Nederland omhoog	✓	✓	✓	20-100	100	1-5
T Drijvende kassen	✓	✗	✗	-	-	-

* Need sand nourishment every 1-5 years to sustain

Figure 17: Selection of the plans

7.3.3 Re-organization of the plans

As the aim of this report is to create and test an evaluation method as a proof of concept (see Chapter 3.2), the amount of plans need to be reduced further in such a way that pathways can be created in the DAPP and as many of the plans have similar characteristics. These plans are re-organized to act as actions in the DAPP. These plans are grouped in the following way:

- **Dike heightening**: corresponding to plan D & G)
- **Broadening the coast**: corresponding to plan H, I, K, L & M
- **Closing inland with sluices**: corresponding to plan E
- **Current situation**: corresponding to plan D
- **Haakse zeedijk**: corresponding to plan F
- **Floating the Netherlands**: corresponding to Plan R in combination with other actions to reduce storm-surge ect.
- **Raising the Netherlands**: corresponding to plan P, potentially also R and T if protected against storm surge and wave load as well

As explained the plans that did not meet the main requirements can act as potential additional actions in the DAPP (Plan A, C, J, N, Q,R,T).

7.4 Conclusion

The selection method is developed to select plans that are suitable for the DAPP. The developed selection method first selects on main requirements after which the remaining plans are given an indication of the range they are applicable for in the DAPP. In this way the plans can be dynamically added in the DAPP. In the end however, re-organizing the plans with similar characteristics into actions, helps to create a more general DAPP in chapter 8.

8 Creating the DAPP Framework

8.1 Introduction

In this chapter the DAPP Framework is created using the plans listed in chapter 7, these plans are use to select the actions that will form the vertical axis of the DAPP. After that a first DAPP is created based purely on SLR. That is then followed by an iteration to finalize the DAPP, this iteration creates a more realistic insight by adding lifespan and construction time.

8.2 Selecting actions

As mentioned above the DAPP will be designed based on the plans listed in the previous chapter, see the plans with corresponding letter in figure 17. These plans were re-organized in chapter 7. However, as only broadening the coast is not sufficient to protect the whole coastal area of the south west of the Netherlands against SLR this plan is combined with dike heightening or closing the inland with sluices, to create the following 6 actions listed below.

I. **Dike heightening & Broadening the coast** - Plan D & G and plan H, I, K, L & M

II. **Closing inland with sluices & Broadening the coast** - Plan E and plan H, I, K, L & M

III. **Current situation** - Plan D including maintaining the dikes and the Delta Works

IV. **Haakse Zeedijk** - Plan F

V. **Floating the Netherlands** - Plan R in combination with other actions to reduce storm-surge ect.

VI. **Raising the Netherlands** - plan P, potentially also R and T if these plans improve by also protecting against storm surge and wave load.

8.3 Setting up the DAPP

As mentioned in chapter 6.2 the maximum SLR rise that this research is focusing on is 5 meters, so step one is to create an horizontal axis from zero till five meters SLR. The actions are then used to create the first DAPP, which is purely related to SLR, see figure 18.

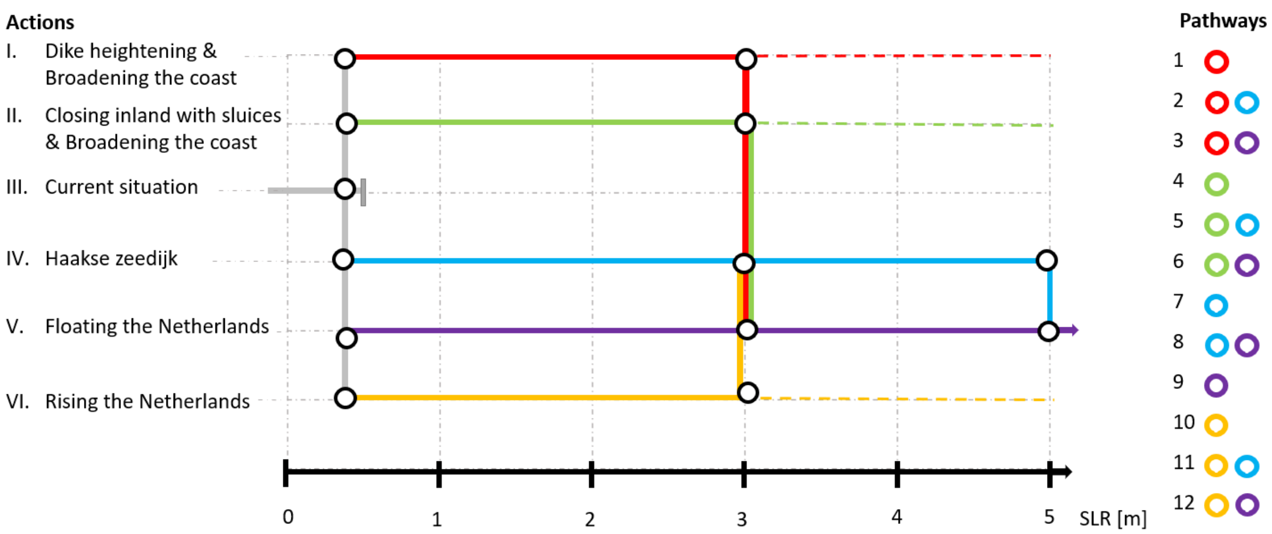

Figure 18: First set up of the DAPP, only focusing on SLR resistance

The current situation which is maintaining the coastline, dikes and the Deltaworks (action III) is assumed to be sufficient for a SLR of 0.5 meter as then the Delta Works do not suffice anymore, see chapter 6.3. A choice has been made for a different action, thus creating a pathway. As most of the plans corresponding to action I, II and VI suffice for a SLR of around 3 m, see chapter 7, the pathway stops here. The actions might suffice for a higher SLR resistance if at the time of construction a higher SLR is taken into account or when there is an option to add upon the build construction. At this point the choice has to be made to take another pathway. The Haakse Zeedijk, action IV, is design for a SLR of 5 m therefore the action stops here, while action V, could continue in time. This results into 12 possible pathways that can be created until 5 meter SLR, see figure 18.

8.4 Iteration

To make the DAPP a method that can help policy makers it is essential to include time. This is done by first adding a horizontal axis which include time. Based on the applicable range of the plans found in chapter 7, the SLR in chapter 6 and the objective of this report as it is most interesting to look at the extreme SLR as predicted by RCP 8.5. This RCP scenario means a relative short time span and a high SLR. This will force the creations of pathways, as not all actions are sufficient for the highest SLR, but it will also not look to far into the future. The RCP 8.5 is also interesting because it might show that in order to prevent flooding, some actions already need to be taken now.

After adding the horizontal axis, the construction time is added to each of the actions and after that the lifespan of each action is included. Since the actions are grouped, the construction time and lifespan are the maximum times. The data used is the same as can be found in Figure 17. This gives room to drag the action over their horizontal axis and see if you can connect them. Of course this still leaves multiple options of placement. Take for example the lessons learned in chapter 6 into account. One of the lessons was needing urgency to realise plans, meaning that actions with a lot of consequences like the Haakse seadike will probably be postponed as long as possible.

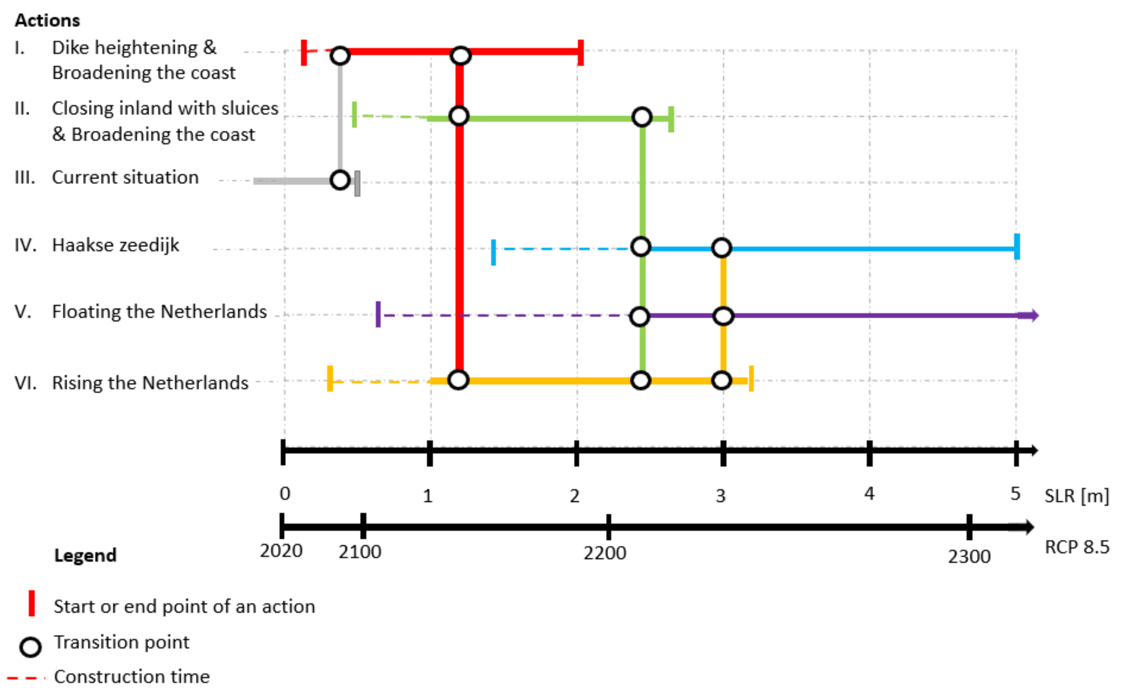

Figure 19: DAPP iteration including lifespan, construction time and timeline of RCP 8.5

The iteration starts at 5 meter SLR (the end of the horizontal axis) of DAPP 1, figure 18. From this point looking back, it showed that there are only two plans that go up until 5 meter SLR resistance, so these plans did not have a lot of room to move over their horizontal axis and are therefore the considered the two end stations. From there on, actions where moved the horizontal axis in order to still create possible pathways, see figure 19. In this case it made sense that broadening the coast is the best way to start, as this is already happening in some places so it is easy to build upon that. This means that there was a gap in between actions, which then could only be filled by action II and V, creating six pathways.

As this is a proof of concept the DAPP is not iterated again, but ideally the DAPP is finalized by evaluating the pathways and looking for vulnerabilities and opportunities, to see if some minor adjustment might optimize the pathways/strategies.

8.5 Conclusion

DAPP gives an good inside into possible strategies to protect against SLR. An even more detailed DAPP will give even more inside, think for example about adding lead time instead of construction time. The DAPP presented in this report shows that there are relative few scenario's remaining if the extreme SLR prediction comes true and that the first steps towards a save future need to be taken in the next 50 years.

9 Development of an evaluation method

9.1 Introduction

This chapter describes what method will be used to evaluate the pathways in the DAPP. This evaluation happens with the help of criteria. The criteria that are used are formed from the characteristics that are extracted from the expertise of the old watermasters, the new watermasters, a stakeholder analysis (see chapter 6) and from a brainstorm session. The PESTLE method is used to make sure no important criteria are missing and to divide them in different categories. An objective tree is used to place the different categories from the PESTLE in a hierarchical structure, which is used to determine weighting factors. After this procedure, the criteria will be placed in a Multi Criteria Analysis (MCA). This MCA will evaluate the pathways in such a way that each pathway is graded based on the different criteria with different weighting factors. At the end of this process, each pathway receives a grade which gives an indication of how good the pathway fits in the dynamic adaptive design and so reduces the flood risk.

9.2 Defining the criteria

In order to properly evaluate the pathways, it is important to use good criteria. These criteria are extracted from the characteristics that are formulated in chapter 6. In this chapter 6 research is done into the stakeholders, the old watermasters and the new watermasters. The idea behind this is that the most important extracted characteristics from these sources provide a complete picture of the situation and so help to define the criteria. Beside these three sources, attention has also been paid to personal impressions of possible criteria. This is done with the help of a brainstorm session in where the group members discuss the addition of possible criteria and this is done with their TU Delft experience from courses.

9.3 Categorizing the criteria

In order to to divide the large group of criteria into smaller groups, the PESTLE analysis is used to place the criteria in different categories. This is of importance because with the help of these categories, the criteria can be more specific which improves the evaluation of each pathway. Also, at the end of evaluating a pathway, the categories receive a grade, from which can be learnt on what categories a pathway scores good. The PESTLE method is described in chapter 6 and therefore the description of PESTLE is not repeated in this chapter. The letters in the word PESTLE stand for Political, Economic, Social, Technological, Legal and Environmental and they form the categories in where the criteria are divided. With the help of a table, the criteria are clearly divided per category in a structured way in appendix E.

9.4 Short description of criteria per category

1.Political

Criterion 1.1: Good phaseability

According to the old watermasters, small adaptations at a time result in easy political implementations and so a quick output of the project. The default for the government to implement actions is lower for a group of small adaptable plans. This is because this group of plans have a good phaseability since they will be implemented sequentially. For example the Haakse Zeedijk, where there is not chosen to place a huge seadike in one go, but the Haakse Zeedijk is sequentially implemented in phases.

Criterion 1.2: Fast realisation time

A fast realisation time of used actions means that an action is easy to fit in during the 4 years of an active government and that there is no or little overlap between different reigns. This is good because the active government can determine a lot in that 4 years of reign. After 4 years another government will be in charge with other plans on the agenda and so they maybe slow down or stop the project.

2.Economic

Criterion 2.1: Creating economic opportunities

When the implemented actions create economic opportunities, they provide a way of earning money which is a positive aspect of the project. An example is a broadening of the shoreline that functions as a flood defence but at the same time provides lots of space for potential housing.

Criterion 2.2: Limited economic damage due to implemented actions

It is of importance that the implemented actions harm the surrounding area as little as possible from an economic perspective. For example; when the port of Rotterdam is blocked because of an implemented flood defence, it will result in a lot of economic damage because vessels can not enter the port. Another example is salt water intrusion, due to implemented actions that can result in agricultural damage.

Criterion 2.3: Limited costs of actions

Low investment costs and low maintenance costs of the actions that are going to be implemented have a positive effect on the project. This is because low investment-cost are attractive for investors, so also for the government that is often guided by the cost. Low maintenance costs are always positive because this comes back every year.

3.Social

Criterion 3.1: Limited negative impact of actions on citizens

The implemented actions should not have a big negative impact on the citizens that live in the surrounding area. Examples of this are: 1. Visual pollution because of a huge sea dike that is constructed around houses and so the sea is not longer visible anymore. 2. A reduced accessibility because of a flood defence that is removed. For example, when the Haringvlietdam is removed, the accessibility of the area is reduced because people have to detour a lot.

Criterion 3.2: Create natural and recreational benefits with the implemented actions

It is desirable when the implemented actions lead to the growth of nature and recreational areas. For example: inter-tidal areas provide possibilities for wildlife and recreational areas like lakes provide extra relaxing for people. Public natural areas provide for both the people and nature a good environment.

4.Technological

Criterion 4.1: Good reliability of the system

It is of importance that the implemented actions that function as a system provide a reliable basis for the whole flood defence. For example when big electrical pumps are used to pump away tons of water and they fail at a certain moment, the system should switch over to backup pumps. When these backups fail, it can lead to failure of the complete flood defence. This level of reliability of the system is therefore important to check how reliable the actions are that could be implemented in the future.

Criterion 4.2: Functional performance of actions matches the actual trend of SLR

It is of importance that the designed action corresponds as closely as possible to future sea level rise. An underdesigned action can result in flooding of the hinterland. An overdesigned action can result in extra use of building materials and thus increasing costs. A design that is closely related to the actual sea level rise will result in a positive outcome floodrisk and for material cost.

Criterion 4.3: Good removability at end functional lifetime

When an action is reaching the end of its functional lifetime, it is of importance that it can be replaced by new actions. This will go smoothly when the old action can be removed easily. Nothing is more difficult than replacing a flood defence that is at the end of its lifetime by a new flood defence when it is almost impossible to remove. For example, it is difficult to remove the Oosterscheldekering when its functional lifetime is expired.

Criterion 4.4: Good coherence between actions within a pathway

When there is good coherence between actions in a pathway it results in a better and more complete pathway. This is because a smooth transition between actions can take place. In this way, the pathway with its actions are working together as one.

5.Legal

Criterion 5.1: High safety during user phase

The consequences of failure of actions can be disastrous. This can result in many deaths. The main goal of this project is to make sure the risk of flooding is as low as possible. This results in the implemented actions needing to work properly to provide high safety during the user phase.

Criterion 5.2: High safety during construction

Possible hazards during construction can be dangerous for the construction workers and the surrounding area. For example, a closure dam where the last part needs to be closed. This is complex due to high flow speeds in the remaining open gab. At that moment, there is the risk that this last part of the closure dam is not closed correctly. When this problem arises, the risk of a flooded hinterland increases and so the safety of the people decreases. Rainbowing of sand to broaden the beach is less complex/hazardous, so the safety of the construction workers and the surrounding is more guaranteed.

Criterion 5.3: Easy implementation of actions that following the dutch laws

The Haakse Zeedijk, for example, needs approval from the EU and GB, and so it takes more time to implement this action because it is harder to reach a legal agreement. A quicker implementation time means that the action can be put into operation earlier.

Criterion 5.4: Limited expropriation of citizens due to actions

In some cases an action is implemented and due to this, a lot of citizens are forced to move from their current accommodation to an accommodation in another area. According to Hobma & Jong (2016) the government can use this law when the safety of the society is jeopardized. This is very annoying and disadvantageous for many of the residents concerned but it is also very expensive for the government itself. This kind of expropriation therefore is not a popular method to use.

6.Environmental

Criterion 6.1: Limited emissions during construction (N2, CO2, etc.)

The amount of emissions emitted during the construction phase of an action is of importance for the environment. This is because emissions like N2 and CO2 have a bad influence on nature and global warming. In the Netherlands, the Stikstofwet (nitrogen law) is used to make sure that the emissions during a project stay under a certain level, which can cause delays/problems in the execution of an action. A low emission during the construction phase therefore needs to be taken into account. For example, the plan of the Haakse Zeedijk has a really high emission mainly because a lot of concrete is used. Plan Waterman has a really low emission because natural materials are used.

Criterion 6.2: Use of eco-friendly methods

Building with nature is beneficial for both nature and people. When designed properly, this multi-functional use of nature provides safety for the people for the long term and at the same time it provides natural growth. A good example of a plan that use this eco-friendly method is plan Waterman.

Criterion 6.3: Limited interference of actions in biodiversity equilibrium

Little to no interference of the actions in biodiversity results in a equilibrium that makes sure that flora and fauna can survive in the way it is doing at the moment. For example, certain species of fish thrive when able to migrate. When dams or other flood defences block this migration, it will result in starvation of some fish species. So, limiting the interference in flora and fauna may create a safe environment where there is the possibility for nature development.

9.5 Weighting the criteria

In this subsection the method used to determine the weighting factors of the criteria is explained. This is done by determining a hierarchical order of importance (to reach the goal of reducing flood risk) for the six different groups of the PESTLE method. This hierarchical order will be used to determine weighting factors for each category of the PESTLE. After doing this, Political for instance has a weighting factor of 10 (as explained later is this section). This factor 10 is then divided between the different criteria that are part of the Political category.

9.5.1 Weighting factor per category

The hierarchical order is determined by making an objectives tree(see figure 20). The objectives tree starts with the goal of reducing flood risk on top. This goal is reached if a pathway consists of actions that are technologically and politically sufficient. When a pathway is technologically not sufficient, the actions in a pathway will fail, which immediately results in a failure of the main goal "reducing flood risk". Political also has a direct connection with reducing flood risk, as actions in a pathway needs permission before they can be executed. When the actions are not executed, there will be no reduction of the flood risk. So the technological and political factors have a direct connection to reducing flood risk, which is why they are on top of the objectives tree.

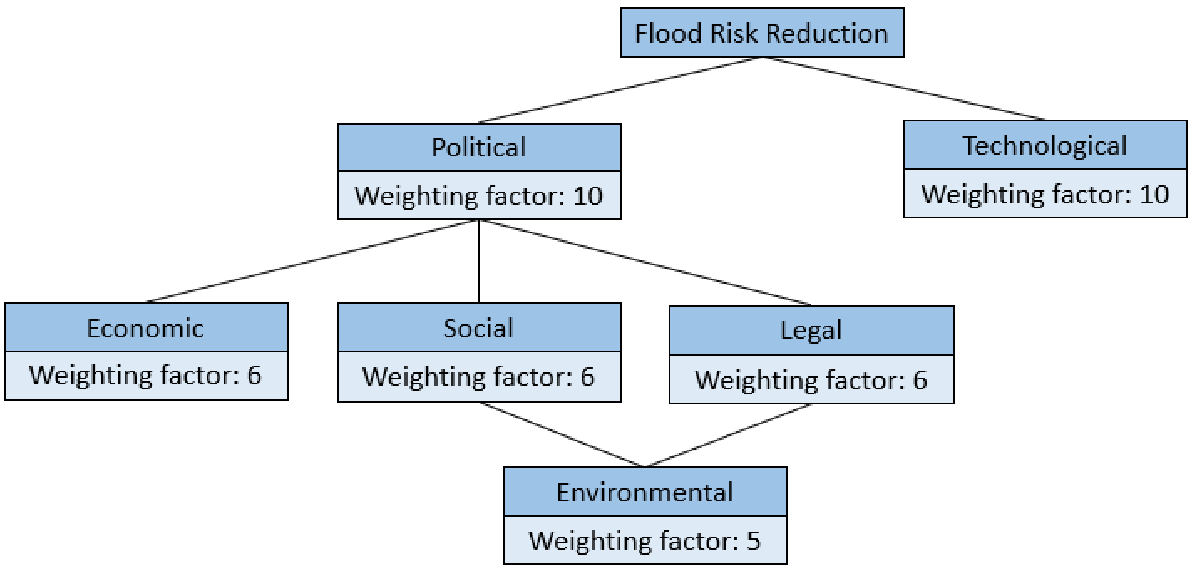

Figure 20: PESTLE categories organised in an objectives tree

The Political factor can be split up in Economic, Social and Legal. For a pathway to be politically implemented, it has to score good from an Economic, Social and Legal point of view. Therefore these categories combined lead to Political in the objectives tree. Also, these categories have no direct connection to reducing the flood risk, while they do have a direct connection to Political. Just like the three before-mentioned groups, Environmental also has no direct connection to reducing the flood risk. It however has an direct connection to the Social and Legal group. Because when a pathway scores well from an Environmental point of view by, for instance, using eco-friendly methods, then it will score good Socially. Also, when the emissions during the construction are low (Environmental), it is easy to implement an pathway legally. If the nitrogen emission during the execution of an pathway are high, problems will arise legally, as there are laws preventing a too large amount of nitrogen emission.

Of course these categories are all somehow connected, but showing the obvious direct connections in the objectives tree in figure 20 gives useful insights for determining the weighting factors. It becomes clear that Politics and Technology are really important for reducing the flood risk (as explained above), therefore weighting factors of 10 will be given to both these categories. 10 is the highest applied weighting factor for a category, from that the other weighting factors per category are determined by estimating the relative importance. Economic, Social and Legal are less important than the top two categories and will be given a weighting factor of 6. Environmental is the lowest on the objectives tree (which aims for reducing the flood risk) and will therefore be given an weighting factor of 5.

9.5.2 Weighting factor per criterion

Now that the weighting factors of the different categories are known, the weighting factors of the criteria that belong to each of these categories need to be determined. This will briefly be described for each category. To do so, the priority is on the objective of this report: reducing flood risk. After that, the focus is on all points that have to do with dealing with uncertainty, because as mentioned in the scope, this is also an important objective of this project. When a criteria has nothing to do with these two points, logical reasoning with the knowledge gained in this project and study experience is applied. The absolute value of the factor per criterion is determined in such a way that, when the factors of each criterion in an category are added, the weighting factor of the category is obtained .

Political
A good phaseability (criterion 1.1) makes it easier to make an adaptable pathway, thus increases the change that it will be implemented. Therefore it will be given a factor of 6, slightly higher than criterion 1.2 about the fast realisation time. This is given a factor of 4, as the connection to adaptability and reducing flood risk is lower.

Economic
For economic 3 criteria are defined, from which 2.2 (limited economic damage due to implemented actions) and 2.3 (limited costs of actions) both have to do with financial costs and 2.1 (creating economic opportunities) is about financial gain. To make costs and gain equally important, criterion 2.1 is given a factor 3 and 2.2/2.3 combined also have a factor of 3. This factor is again split up into 2 for the limited economic damage and 1 for limited costs. As the economic damage of for instance blocking an port can become much larger than the costs of an action.

Social
The first criterion of a limited impact of the actions on citizens (3.1) is given the highest factor of 4, as this is something that can cause large delays and/or cancellation of implementing an action when the citizens protest. The second criterion of creating natural and recreational benefits (3.2) is given a lower weighting factor of 2, as this has a lower chance of a negative impact on the implementation of an action.

Technological
For technological there are 4 different evaluation criteria. From these criteria, 4.1 about a good reliability of a system is the most important and is given a weighting factor of 4. This is because it is very important to be able to rely on a system to reduce the flood risk. Criterion 4.2 about the functional performance of actions matching properly with actual trend of SLR, is the second most important and is given a weighting factor of 3. Because If this is not the case, the structure is over- or under designed which can have a large influence on reducing the flood risk. Next comes 4.3 about the good removeability at the end of the functional lifetime which is given a factor of 2. This has no direct connection on reducing the flood risk, but increases the adaptivity. Last of all, criterion 4.4 about the good coherence between actions within a pathway is given a factor of 1, since it also had no direct connection to reducing flood risk, but increases the adaptivity.

Legal
For the Legal category there are 4 criteria defined, from which 5.1 (high safety during users phase) and 5.2 (high safety during construction) are found to be most important. If the safety is low, the flood risk is increased

and it thus has an direct connection to flood risk. Therefore both is given a factor of 2. Criterion 5.3 (easy implement of actions that follow the Dutch laws) and 5.4 (limited expropriation of citizens due to actions in the pathways) have less connection to reducing flood risk and are both given a factor of 1.

Environmental
Criterion 6.1 about limited emission during construction is given the highest weighting factor of 2. Emissions are an important topic when studying climate change, as emissions increase the climate change which increases the amount of SLR (section 6.2). Also there are some strict laws preventing a large amount of emission, this can cause large problems and/or delays for the implementation of an action and thus has a direct connection to reducing the flood risk. The use of eco-friendly methods(6.2) and a limited interference of actions on biodiversity equillibrium (6.3) have less connection to reducing the flood risk and both are therefore given a factor of 1.5.

9.6 Analysing the Pathways

During the process that each of us were grading the pathways, it was difficult to grade each pathway on the criteria. This is because the pathways exist out of different actions that do individually have another score. Actions within a pathway can differ a lot and to create one final grade per pathway was therefore difficult. This resulted in that most of the pathways had quite a similar score. What also became clear is that there was more time needed to get extra information of the pathway and so to give the pathway a more nuanced grade. With the lack of time and more information the consequence was that subjectivity could emerge, for an a more elaborated view on this is referred to chapter 10.3.3 of the discussion. For broader overview of the MCA grading is referred to appendix E.

Pathway 1: Grade 6.5
Final grade build-up

What emerges during the evaluation of pathway 1 is that this pathway scores well on the category Political with a grade of 7.1. On the categories: Economic, Technological, Legal and Environmental, the score was medium with a grade around 6.5. Pathway 1 scored not so well on the category Social and this grade was around 5.9.

Pathway 2: Grade 6.3
Final grade build-up

What emerges during the evaluation of pathway 2 is that this pathway scores very well on the category Technological with a grade of 7.9. This pathway scores well on the categories: Political, Legal and Environmental with an average grade of 7.0. On the category Social, the score was medium-low with a grade around 4.9. Pathway 2 scored poorly on the category Economic and this grade was around 2.6.

Pathway 3: Grade 6.5
Final grade build-up

What emerges during the evaluation of pathway 3 is that this pathway scores well on the categories: Political and Technological with an average grade of 7.3. On the categories: Economic, Social, Legal and Environmental, the score was medium-low with a grade around 5.7.

Pathway 4: Grade 6.1
Final grade build-up

What emerges during the evaluation of pathway 4 is that this pathway scores quite well on the category Technical with a grade of 7.7. On the category Legal, the score was well with a grade of 7.2. On the categories Social and Environmental was the score medium with an average grade of 6.5. Pathway 4 scored medium-low on the category Economic with grade was around 5.0 and the score was poor on category Political with a grade of 4.1.

Pathway 5: Grade 5.2
Final grade build-up

What emerges during the evaluation of pathway 5 is that this pathway scores not so well overall. On the categories Social, Technological and Legal the score was medium with an average grade of 6.0. This pathway scores medium-low on the categories Economic and Environmental with an average grade of 4.7. On the category Political, the score was Poor with a grade of 3.6.

Pathway 6: Grade 6.6
Final grade build-up

What emerges during the evaluation of pathway 6 is that this pathway scores very well on the categories Technological, Legal and Environmental with an average grade of 7.9. This pathway scores quite well on the categories: Economic and Social with an average grade of a 6.5. Pathway 6 scored poorly on the category Political and this grade was around 3.6.

9.7 Conclusion

The outcome of the Multi Criteria Analysis is that pathway 6 had the best score with a grade of 6.6. Good aspects of this pathway is that it scored good high on category Technological with grade 8.3. Also categories legal and environmental scored high with grades 7.7 and 7.8. On the category Political was the score poor with a grade of 3.6. also Economic and Social scored not very well with grades 6.8 and 6.2. These last three categories are important because there must be support from several parties before a plan is actually implemented. A plan may score high technically and legally but will ultimately not be used as long as the deciding parties decide on an approval. In order to increase political support for this plan, it is therefore important to design the pathway in such a way that it scores higher in the Multi Criteria Analysis on the categories Political, Economic and Social.

10 Discussion

In this report an initial proof of concept for an evaluation method is presented. Since this was an initial design there's a lot to be learned from what went well, as well as what could be improved upon. In this chapter, the process of this project will be discussed. Starting with a newly suggested approach and discussion of a more general evaluation method to be used in future projects. After this, the various steps of this general approach will be discussed in relation to what was done in this project.

10.1 Approach

After working through the initially proposed approach in this report, it seemed to be inadequate (see figure 2 chapter 4). This was especially due to the lack of a connection between the analyses and the selection requirements. This will be further explained in section 10.4. Additionally, there was no feedback between the DAPP evaluation and the scope. Therefore, a new general evaluation approach that is based on this initial approach is proposed. This approach can be seen in figure 21. A more extensive explanation of the steps in the newly proposed approach is given in their respective sections in this chapter, as well as a discussion of the improvements compared to the old approach.

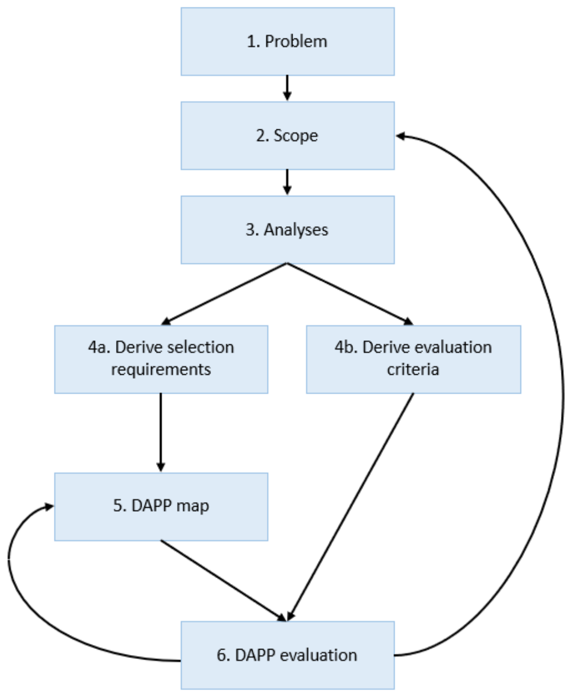

Figure 21: The general evaluation method

Feedback loops

Next to the link between analyses and the selection requirements, another point of discussion are the feedback loops in the approach. There are two feedback loops, both from the DAPP evaluation. One of these goes back to the scope and one goes to the creation of the DAPP map. The feedback loop back to the scope is due to a potentially changing scope as time goes on and certain parts become more or less important. This change in scope in return has an effect on the outcome of the analyses in step 3, which in turn affects the requirements and criteria derived. It is thus also suggested to use this loop when changes in the results of one of the analyses are expected. The second feedback loop goes from the DAPP evaluation back to the creation of the DAPP map. This is characteristic of the DAPP approach, where the pathways are partly constructed based on the feedback from their evaluation.

When to start with these feedback loops is still unclear, however. Regarding the first feedback loop, it is hard to know when the scope needs to be revisited since changes in the scope happen gradually over time. One way to deal with this could be to revisit the scope at a specified time interval.

10.2 Step 2: Scope

Due to time constraints, and to reduce complexity, this project was scoped extensively. In future projects, while it is still advised to scope sufficiently, the scope can definitely be broadened a bit. Some questions that in this project helped to reduce complexity were:

- What are the main drivers of flooding that will be taken into account?
- Which region is to be protected from flooding?
- What kind of plans will be taken into account?

To talk more specifically about the scope in this project, there are some parts that would be advised to change in following research. First of all, the scope did not include the influence of the rivers. While for a first attempt this was fine as otherwise the research would have become to complex, in reality the rivers have a large influence on the functioning of the different plans. Second of all, the area that was scoped was the South-West of the Netherlands, including the harbor of Rotterdam. In future research, it is advised to take into account the dike rings, as this might be a more functional way of dividing up the Netherlands. This is because every spot in a dike ring should have the same risk of flooding.

10.3 Step 3: Analyses

To gather the evaluation criteria in this project several analyses were done. The criteria gathered from these, as well the process of these analyses will be discussed further in section 10.5. The analyses done were helpful, and led to a broad range of different criteria. However, it is not known if different analyses could have led to different results. Additionally, currently the selection of techniques was holistic. More research should be done into the main benefits of each different analysis, to further motivate the choice for certain techniques. The inclusion of an analysis of old and current successful projects was considered especially helpful. This was considered a good replacement for expert opinion, as their principles are already implicitly included in these plans.

10.4 Step 4a: Derive selection requirements

Main requirements
To select plans to be used in the DAPP later on, the first step was to come up with main requirements to make a first selection of the plans. For this step the focus was on the main goal of the report, which is protecting the coastal south-west of the Netherlands against floods. To do so, the book of bed, bank and shore protection was consulted. From this book, three critical loads a plan should protect against were defined as main requirements: SLR, storm surge and wave load.

There are plans, like for instance "Plan Emergo", which only reduce the wave load. This plan cannot act solely as a complete flood protection plan for a certain location, since it needs other plans to protect against the rising sealevel and storm surge. This makes these 3 main requirements good to filter out all the incomplete plans. This was very helpful while creating the DAPP, as creating the DAPP can become complex very fast. Only taking into account plans that protect against the 3 main requirements makes the creating of pathways in the DAPP much more straightforward. Next to that, the filter also makes sure that each different plan achieves the goal of protecting against floods.

Proceeding on the main requirements, next to the positive points, there are still a lot of opportunities with the main requirements. In chapter 7 the plans were reduced from 20 to 15, which is a reduction of 25%. On the Deltares site (Deltares, 2021), where all the plans can be found, there are over 100 plans. If the same reduction percentage would be reached as in this report, there would still be many plans(75+) left. Next to that, the main requirements are only aimed at the three critical loads. These are important for protecting against floods, but are only technological aspects. From the old and new watermasters presentations, discussion with the supervisors and the knowledge gained from courses at the TU Delft, it is known that these are not the only aspects that are important. This means additional requirements to the 3 main requirements mentioned in this report should be established.

In contrary to the main requirements, in chapter 9 a broad spectrum of aspects were taken into account for the evaluation criteria. For setting up these criteria, the old and new watermaster presentations, stakeholders analysis and the PESTLE method was used to take every aspect into account as good as possible. Weighting factors were determined for the evaluation criteria and the PESTLE categories they belong to. From the weighting

factors can be learnt which criteria are the most important and thus can be recommended to be added as an requirement in next projects. It should be noted that these weighting factors were determined with the aim on reducing flood risk and dealing with uncertainty (the objectives of this report). So the criteria with a high weighting factor, are due to this not aimed on for instance environmental aspects like limiting emissions. To include also these kind of aspects as requirements, more research is needed.
From the objectives tree, it can be concluded that next to the technology category, the political category of PESTLE is also critical. The criteria that are part of this category are phaseability (which is aimed at small adaptations at a time) and a fast realisation time of plans, which both result in an easy implementation of plans politically. For plans to be realised, they have to be authorized politically. Therefore, for aspects like this it can be considered to take this as an main selection requirement in further projects.

From this discussion it can be concluded that the main requirements used in this project are a good starting point, but they are only focused on the technological part of reducing the flood risk. To keep a wider perspective on selecting plans, it is firstly recommended to take into account the before-mentioned political aspects. Next to that it is advised to take a closer look at requirements from, for instance, an environmental and economic point of view. For this, experts from these fields should also be consulted, as both the sources and students of this project all mainly have a technological background.

10.5 Step 4b: Derive evaluation criteria

Defining the criteria
To define good criteria, analyses of the presentations about old and new watermasters, a stakeholder analysis and a student brainstorm session were executed. To decrease the chance that any criteria were missing, they were organized with the PESTLE method, which consists of the 6 different categories: Political, Economic, Social, Technological, Legal, and Environmental. First it will be discussed what went well, and afterwards that which could be improved.

Overall, this method of deriving the criteria seems to be a good method to use. Taking lessons from the old watermasters who already have one or more of their plans implemented makes them the perfect source to gain knowledge in what is needed for a plan to be realised. The new watermasters, who are working on flood protection plans for the future in their daily life and have a lot of experience in the current engineering field, are also a good source to gain knowledge in what aspects are important to consider nowadays. The stakeholder analysis also gave insight into what is considered important nowadays, but from the perspective of a variety of stakeholders.

In the end, doing a student brainstorm session resulted in some new aspects to consider, but did not really lead to the incorporation of new aspects in the criteria. This means that the analyses of the old and new watermasters as well as the stakeholder analysis already gave a good overview of the most important aspects to take into account. However, due to the Covid 19-lockdown it was impossible to organize a good brainstorm session involving all of the supervisors of the different disciplines. Their thoughts could result in some additional aspects to take into account, as they are experts in their disciplines.

Also, the project group members were mainly exposed to presentations of the old and new watermasters in the first 2 weeks. This might cause tunnel vision on the topic and could make it harder to think of new aspects in a brainstorm session. Doing a brainstorm session before the presentations could potentially solve this.

Last of all, most of the sources and group members have a technological background. This causes the possibility that some of the categories are incomplete like for instance the economic or legal category of the PESTLE. Involving experts on this fields of study could result in an more complete overview of the evaluation criteria to take into account.

Using an objectives tree
The use of an objectives tree to categorize and structure the derived criteria was found to be very useful. Having an objectives tree made splitting up criteria into groups and assigning them weights much easier, which made the implementation of the MCA much easier. It also clearly visualized the importance of each of the PESTLE categories in achieving the main goal, protecting the South-West of the Netherlands against flooding.

An improvement that could be made is using a means-ends analysis to arrive at more fundamental objectives or criteria (Keeney & Keeney, 2009). This is done by organizing the objectives in hierarchical structures to derive fundamental objectives or criteria. These fundamental criteria could be useful since they change less throughout time (*Separating means from ends*, 2013). This means that the evaluation method is made more suitable for planning further into the future, making the method more robust.

10.6 Step 5. Building the DAPP map

Applicable range
The plans remaining after selection based on the main requirements were given an indication of the range they are applicable for in the DAPP. The applicability range is indicated for the construction time, functional life time and SLR resistance. These aspects are needed to build the structure of the DAPP, and are all either based on time or SLR resistance. The applicable range does not help in selecting plans, but gives a range of when plans can be implemented. It was difficult to make the DAPP since there were still too many actions. This is why different and/or more (main) requirements should be considered to lower the number of plans that will be added in the DAPP, see step 4b, or they could all be integrated in an interactive method, see next section. The applicable range worked well, however the lead time only encompassed the time it took to construct a plan. Including the time policymakers take to finally to give the green light for the project in the lead time could give more realistic results. For this expert knowledge on politics is needed.

Increasing adaptivity
During the duration of this research only one SLR scenario was considered. In order to make the DAPP even more adaptive, it is important to look at other predictions and see how that could potentially change the pathways. This is because only when the complete picture is known, the right advice can be given. This could, for example, give better insight what might be the best or safest option to start with without excluding certain plans in advance, which currently makes the entire process more static.

Increasing dynamics
The final iteration from the DAPP, in figure 19, leaves room to move certain actions back and forth, but in a figure this is not visible. Creating an application to move and add plans, based on certain inputs like the ones found in the selection and evaluation criteria could give new watermasters insight into the effects of their plans, as well as its adaptivity.

An idea how to implement this could be inspired by the 'planning kit' used for the room for the river project. This kit helped to cope with the objectives of 39 measures to lower the flood level of the River Rhine and its branches in the Netherlands using multiple (hydraulic) models. The results gave a comparison of the various measures with the flood levels at various location, together with an estimation of costs. Since this was successfully used to take well-informed decisions, this might also help in this case (*Room for the river*, 2021).

Increasing professional input
During the creation of the DAPP, only construction time was considered but for some of the plans political change is needed. This has the potential to double the construction time from what it is now, potentially limiting the pathways by making the lead off time significantly higher. To lower this, the input from experts on politics is needed on how to make plans more politically acceptable.

There is a similar necessity for getting professional input on the financial side of things. Even though it is currently an evaluation criteria, the input and expertise in this field is still very limited. This is a problem, since in reality finances are a major factor when determining a project's success (Group, 2019).

The input from the new watermasters is also important as some plans are more dynamic then they appear to be on paper. This means speaking with these experts could give more insight in how actions could be divided into multiple actions creating more pathways and increase adaptivity. As a phaseable example, a plan could be built without locks first, protecting up to a certain level and when that level is reached, the locks could then be added increasing the resistance against SLR.

10.7 Step 6: Evaluation of the DAPP

Weighting the criteria
To determine weighting factors, an objectives tree was used to give weighting factors to the different categories in which the evaluation criteria were sorted (with the PESTLE method). After doing this, the weighting factor for each category was divided in criteria that were part of the category, so the sum of the weighting factors that are part of the category ends up in the weighting factor of the category. This division happened by first focusing on the objective of reducing flood risk, after that on criteria that have to deal with uncertainty(part of the scope) and as last logical reasoning with the knowledge gained in this project and study experience.

The applied method made it easier to determine the weighting factors of each criterion. As in this way the choice for the value of the weighting factors was well organised and it was easier to illustrate different choices. There is no formula to come up with the exact value for weighting factors, so always some kind of subjectivity will remain. All in all this subjectivity was reduced a lot with applying this method.

The whole method was aimed on the above mentioned objective and scope of this report(reducing flood risk and dealing with uncertainty). While this are also in reality very important aspects to consider(two of the most important at this moment), a category like the environment is considered less important with this method(lowest on the objectives tree). This causes a relatively lower weighting factor for this category. However, from the old and new watermasters presentations, discussion with the supervisors and courses followed by some the students, it becomes clear that this an important category to consider. How to deal with this is in an scientific way is still something that needs some thoughts.

As last, the determination of the weighting factors for the criteria that are part of the economics category for instance gave some problems. As the members of the project group don't have much experience/knowledge about that parts, it was hard to say what is more important(and thus what needs a higher weighting factor). Also because this category has an less obvious connection with the objective and scope of this report. This could be solved by involving experts on the different categories.

Evaluating the pathways
For evaluating the pathways, a multi-criteria analyses was performed with the determined criteria and weighting factors. Each member of the project group gave grades to each criteria to decrease the subjectivity of grading as much as possible. The grades in combination with the weighting factors resulted in a grade for each category and a final grade for each pathway.

With the grades per category, it was easy to see in what categories a pathway scored good and in what categories a pathway scored bad. This helps a lot when you want to compare pathways with each other and want to see what a pathways good and bad characteristics are. Also, if for instance pathway A scores bad on an environmental point of view and pathway B scores good on an environmental point of view, you can try to include good aspects from pathway B in Pathway A. In that way you can improve pathway A in an environmental point of view and thus also improve the overall grade of pathway A.

Besides the positive aspects about the evaluation method, there were some major points that need improvement. First of all it was very hard to grade a pathway with the limited knowledge the group members have about the actions in a pathway, as the information on the Deltares website Deltares (2021) from which the actions are extracted is limited. For instance grading "limited economical damage due to implemented actions", it is hard to determine an grade for this in a short time notice and with the limited information available. Next to that, with the limited academical background the group members have about some of the categories (like economical), makes grading even harder. This can be solved by increasing the amount of information available about an action on the Deltares website.

Furthermore, it was hard to grade a whole pathway, while the actions in the pathway differ a lot. When you have for instance an pathway that starts with a beach nourishment(broadening the coast) and ends with the "Haakse Zeedijk", then it is hard to determine the grade for the criteria from the environment category. As the first action scores good and the last action scores bad on environmental point of view. This could be solved by grading actions in stead of pathways. From that a grade for a pathway can be determined by averaging over all the actions in a pathway.

Concluding about the whole evaluation process, the applied evaluation method is good to be used in the future to evaluate actions/pathways. Having said that it first needs some changes as described in the text above, these changes will be repeated in chapter 11 in the recommendations part.

11 Conclusion

In this report, a method for the evaluation for different plans was designed and described. This was done in order to reduce the flood risk in the south-west of the Netherlands. The criteria for the evaluation method were derived from plans of old and new watermasters, as well as from a stakeholder analysis. These were then placed in a PESTLE (Political, Economic, Social, Technological, Legal, Environmental) framework, and assigned different weights. To test and develop this method, a case study was done, using the south-west of the Netherlands including Rotterdam harbor. The different plans for this region were placed in a DAPP map, and the different pathways they made up were in turn evaluated. Because the object of this project was a design, the conclusions mainly have to do with the process of designing the evaluation method for different plans.

Main requirements aimed on flood risk reduction works well, but are not sufficient
It can be concluded that the main requirements(protect against SLR, storm surge and wave load) used in this project are a good starting point, but they are only focused on reducing the flood risk (only technology). To select plans on a wider perspective(also Political, Economic, Social and Environmental) the main requirements are not sufficient.

A DAPP approach works well
One of the first conclusions is that using a DAPP approach is a satisfactory method. This is mainly due to two reasons. The first reason is that current plans are static, which is a problem when planning for deep uncertainty. Static plans are optimized for a certain projection of the future. When the future turns out to be different than this projection, however, they quickly lose effectiveness. By using a DAPP approach, these static plans are combined into a comprehensive mitigation strategy.

The second reason is that in order to evaluate a plan, it has to be put into the proper context of its role in a flood protection. Without this context, it is nearly impossible to properly assess the opportunities and vulnerabilities a plan presents as compared to either no implementation, or the implementation of another plan. It was chosen to integrate the different static plans into a DAPP approach in order to create this context.

Evaluation criteria can be successfully derived from current and historical plans
The second conclusion is that the evaluation criteria can succesfully derived from the lessons learned from the old and new watermasters. The old watermasters who already have one or more of their plans implemented, makes them the perfect source to gain knowledge in what is needed for a plan to be realised. The new watermasters, who are working on flood protection plans for the future in their daily life and have a lot of experience in the current engineering field, are a good source to gain knowledge in what aspects are important to consider nowadays. This can also be learnt from a stakeholder analyses, but than from the perspective of a variety of stakeholders.

Organizing criteria using a PESTLE framework and objectives trees has significant benefits
Lastly, the use of a framework to divide up the different criteria was useful. Structuring the different criteria helps to check if the list of criteria is exhaustive, as well as making it easier to assign weights to different criteria. In this report a PESTLE framework was used, which was considered as satisfactory seeing as it encompasses most of the impacts a plan can have. Furthermore, by using an objectives tree the importance of different categories of criteria is apparent.

12 Recommendations and ideas for future projects

12.1 Recommendations

As described in the discussion in chapter 10, the following recommendations are advised to be implemented in further research:

Involving other experts via brainstorm sessions to obtain evaluation criteria
Organize a brainstorm session to obtain evaluation criteria at the beginning of the project, before the start of the research, to make sure that the researchers can come up with evaluation criteria without being biased. Later, during the research, organize a second brainstorm session with experts of different disciplines, to make sure that no important evaluation criteria are missing.

Experts of different disciplines (like economics and politics) should be involved when having a brainstorm session about evaluation criteria and determining weighting factors for the criteria. This is to increase the reliability of the evaluation.

Evaluate actions and pathways
The actions and pathways should both be evaluated, instead of just the pathway as a whole. This is because additional actions might arise, and by having each action evaluated, building pathways becomes easier. Additionally, the evaluations of the actions can be used to evaluate the pathways. This increases the reliability of the result of the evaluation.

Additionally, a means-ends analysis should be done to further organize the different criteria, and to arrive at fundamental criteria. These fundamental criteria would be more robust for changes in priorities in the future, as also explained in chapter 10.

Re-define a selection method to select plans
In the case of this research, a few selected plans were analysed for critical characteristics. In order to to give a tool to policy-makers to assess various plans easily all plans need to be evaluated. During this research, the number of plans that were selected based on the selection method were in terms of percentage relatively high, so redefining the selection requirements is also necessarily.

Explore different adaptive planning approaches
During this research a DAPP approach was used in order to best evaluate the different plans. Since different approaches have different limitations it is advised to also look at other methods to select and evaluation plan.

Re-define requirements in an wider perspective
From the discussion can be concluded that the main requirements used in this project are a good starting point, but they are only focused on reducing the flood risk (only technology). To select plans on a wider perspective, it is firstly recommended to take into account the political aspects, as it was concluded that this is an very important category. Next to that it is advised to take a closer look to requirements from for instance an environmental and economical point of view. For this, also experts from these fields should be consulted, as the sources and researches of this project all have an technological background.

12.2 Ideas for future research

During this research new ideas of future projects came to mind. Below an itemization is given of potential new ideas after that they are elaborated. The future research, lessons can be learned from the recommendations.

- Implement the evaluation method to a different region or country
- Re-define selection requirements in an wider perspective
- Creating an application to make the DAPP interactive

Implement the evaluation method to a different region or country
Apply the evaluation method to a different region or country. During the symposium 'Protecting Delta Floods' of the University of Applied Science of Rotterdam and Stichting de Blauwe Lijn (2021) it stood out that a lot of cities, for example New York City, Taipei and Rio de Janeiro, face the same problem as the Netherlands does as it is located in a delta region. For these cities it might be interesting to implement the DAPP approach with the evaluation method. Also a different region of the Netherlands might be interesting for example the north of the Netherlands with the Waddensea.

Re-define selection requirements in an wider perspective
From the discussion can be concluded that the main requirements used in this project are a good starting point, but they are only focused on reducing the flood risk (only technology). To select plans on a wider perspective, it is firstly recommended to take into account the political aspects, as it was concluded that this is an very important category. Next to that it is advised to take a closer look to requirements from for instance an environmental and economical point of view. For this, also experts from these fields should be consulted, as the sources and students of this project all mainly have an technological background.

Creating an application to make the DAPP interactive
Creating an application to make the DAPP interactive with the ability to move and add plans. This can be inspired by the 'planning kit' used for the room for the river project.

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A Appendix: Takeaways of the presentations

In this appendix small summaries of the presentations given in the first two weeks of this project are given. These presentations were given about a variety of topics by new watermasters, although the influence of the old water masters was readily apparent. Next to summaries, the main lessons that were taken from them are also mentioned. This leads to a first analysis of the old and new watermasters which is elaborated upon in chapter 6.

Presentation 1: Henk Jan Verhagen
How to realise "Great Plans"
Small summary: In this presentation Henk Jan Verhagen gave a small insight into some of the most important old watermasters, as well as taking general lessons from them on how to realise great plans. This is further illustrated by a case study on the implementation of both the Zuiderzeewerken and the Deltaplan, two of the most important feats of Dutch civil engineering.

Lessons learned

- **A plan should have a good technical basis.** When a plan is worked out in detail and the technical aspects have a good coverage, the chance that a plan is implemented increases. Once a plan has a good technical basis, it has the ability to be saved for the future because the end result is already made clear, as will also be discussed in the next point. Having a solid technical basis does not only allow the storing of a plan for a later date, it also helps to calculate the cost and duration of a project more accurately which helps those in power make more well-informed decisions.
- **There has to be urgency. This can be done by finding publicity and/or using catastrophic events.** This means that next to being technically feasible, a plan should also be politically feasible. To be politically feasible, there should be enough political urgency to implement a certain plan. This is also sometimes called a policy window. This was illustrated by Henk Jan Verhagen through the Zuiderzeewerken most explicitly. For the Zuiderzeewerken, the first technical reports were ready as early as 1887. Cornelis Lely, one of the initiators of the plan was a minister three times. Finally, at the start of his third term in 1913, the first steps were taken to reclaim the Zuiderzee, partially due to his long-time lobbying of the plan. Due to this lobbying, at the start of his third term the queen mentioned in a speech the need to reclaim the Zuiderzee. This in turn led to significant publicity around the subject and the tentative start of lawmaking around the subject. Still, severe flooding in 1916, combined with food shortages due to the ending of World War I finally created the necessary political urgency to implement a plan that was proven to be technically feasible more than three decades before. A similar situation happened the Watersnoodramp in 1953, which led to the urgency that was needed to eventually implement the Deltaplan.
- **Experts should fully agree.** To illustrate this, Henk Jan Verhagen pointed to Johan van Veen when he tried to get the Deltaplan implemented. There was much disagreement about the costs and the technical feasibility of the project, as well as on the effects it would have on the fishing economy and biodiversity in the area. By keeping all experts engaged and having an open discussion, the main conflicts were solved before the plan was presented to policymakers. A similar approach was taken when starting sand nourishments in protecting the Dutch coast. All discussion happened behind closed doors, where extensive reports were written detailing the effects of this new measure. By having all experts agreeing beforehand, it made it much easier for the government to implement coastal sand nourishments.
- **A financial basis for a plan is needed, but it is by no means decisive.** A good financial basis for a plan is very important. It makes it easier for those in power to both garner enough money to be able to implement a plan, and to make more well-informed decisions. However, a strong financial basis is not decisive for the implementation of a plan. The example given by Henk Jan Verhagen was the maintenance of the coastline that started in the 1990's. This maintenance, while not profitable, did much to improve the living conditions of those near the coast by the implementation of sand nourishments every 2 to 5 years. Because this plan raised overall living standards, it was easy for the government at the time to implement it and to make it one of the most important aspects of their coalition agreement.
- **Adhere to laws now and in the future** The world is constantly changing. This, of course, also applies to the laws used to keep society running. It is of importance to pay attention to possible changes in laws,

as well as to make sure a plan follows the current laws before implementation. No laws having to be changed makes implementation much easier. Cornelis van Lely made sure the Zuiderzeewerken adhered to current laws at any time he tried to implement the plan. While he was unsuccessful the first couple of time in lobbying for the reclamation, due to this lawful approach it was possible to implement the plan the moment the political urgency had reached a critical point.

- **Coherence between the big plans.** Good coherence between plans has two main meanings in this context: synergies with different concurrent plans, and synergies with different sequential plans. For the first of these two meanings, the example of the Deltaplan can be given. For this plan, many different protection measures were taken, which all had their own different opportunities and vulnerabilities. By closing off certain branches, and opening some barriers to introduce the tidal forcing in the lagoon behind it, the designers of the plan were able to optimize on these vulnerabilities and opportunities. For the second part, the example of the problems with removing the pillars of the Oosterscheldekering. The current pillars that form the cornerstones of the Oosterscheldekering were, with much trouble, placed and filled with sand. This means that they are also extremely hard to remove, meaning any future plan to protect the hinterland here will have to work around these pillars. This leads to (unnecessary) difficulties.

Presentation 2: Marcel Stive

The Sand Engine: a Nature-inspired answer to Sea Level Rise

Small summary: Due to new policy of the Netherlands since 1990, the coastline is maintained with a sand nourishment every couple of years (2 to 5 years). This is devastating to the local ecology since it has to recover from both the dredging and the placement of these nourishments time and time again. Th at the spots where the sand is placed and where it is dredged. Additionally, these nourishments provide low multi-functional opportunities. Using building with nature, which is defined as integrating natural system elements in "engineered" environments", the sand engine is designed to be able to provide one large nourishment for the next 20 years instead of the multiple smaller ones. The deposited sand plays the role of a "natural feeder" along the coastline, decreasing the amount of dredging and placement necessary by letting nature do the work. Its effectiveness depends on tides, wind speed and coastline location. Additionally, the placement of the sand engine has multiple functions next to sand nourishment: it provides recreation for wakeboarders and extra environment for current species.

Lessons learned

- **Using Building with Nature to create multi-functional new natural areas.** When building with nature, it allows the local ecology to arrive at its own balance. For the sand engine, this can be seen in working with nature instead of unnecessarily interfering. Allowing the Dutch coast to naturally regulate its sediment intake means the coast is kept as natural as possible. This reduces nourishment costs, increases the amount of nature, and decreases the ecological demise due to placement of sand. Additionally, the Sand Engine has extra functions such as recreation and surfing. Lastly, building with nature is still in its earlier stages. This means another function of the Sand Engine, for example, is that it is a huge source of research. It should be kept in mind that in the implementation of other plans there can often be room for research as well.

Presentation 3: Leo van Gelder

Creating inlets in dunes and Spaargaren/sluices

Small summary: The first plan put forward by Leo van gelder is to create inlets in dunes. Creating these inlets("gabs") allows water to naturally flow in during high water. The sediment that is carried by this water in turns helps to naturally reinforce the dunes. While this plan could potentially save money by letting nature do a portion of the work of strengthening dunes, this technique is still untested so it could also potentially work in reverse, removing sediment. An additional concern is that this technique cannot be used for dunes that store fresh water, as it can contaminate this.

The second plan has to do with substituting the Maeslantkering with gel-based sluices. Ships can be pulled through this gel, while it still offers protection to high water. Because gel is used, there is little to no water loss or salt-water intrusion. This latter benefit is especially important when dealing with high SLR, since normally this has to be accounted for with discharge from rivers. However, there are also still some problems. First of all, this gel still in its testing phase so it still needs time until it can be used. Second of all, when the gel fails the damage can be very large. Lastly, the time it takes for ships to travel through a gel sluice versus conventional sluices can be much longer. This makes the port of Rotterdam less attractive for shipping companies.

Lessons learned

- **Lowering project costs by using Building with Nature.** In his plan Leo van Gelder uses man-made inlets in dunes to naturally reinforce them. Reinforcing dunes in this way allows nature to do most of the work. This can save money when compared to for instance reinforcing the dunes yearly with beach nourishments.
- **Preventing salt-water intrusion/fresh (drinking) water storage** Salt-water intrusion is a problem that will continue to become more important as the sea level rises, and that mainly causes agricultural damage and contamination of the fresh drinking water. By using sluices made of a gel this damage and contamination is prevented, even at higher levels of SLR.

Presentation 4: Idco Duijnhouwer
De Banjaard: Living Breakwater
Small summary: Idco Duijnhouwer is a geologist by trade. His idea was to reintroduce sandbanks that existed in the past using Building with Nature. These sandbanks would absorb the energy of the sea, functioning as a natural breakwater. Additionally, this sandbank could help restore this historical sandbasement of the Dutch shoreline, functioning like the sand engine. This is done through a combination of one or more smart sand nourishments at or near the former island 'De Banjaard' and innovative building with nature techniques. Due to the Building with Nature techniques, the hope is that these breakwater islands will grow with SLR. The other points of this plan can also be seen in figure 22:

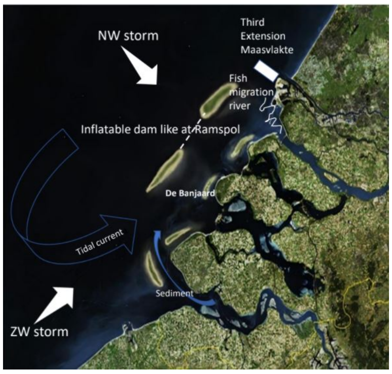

Figure 22: Plan de Banjaard for 1-3 meters SLR

- A third extension of the Maasvlakte
- Restoring the fresh-salt gradiënt with fish migration river
- Inflatable dam (Balgstuw) to protect against a storm surge
- Freshwater storage underneath the dunes
- Trapping sediment of the Scheldt river in the foreshore

There are some problems with this plan, however. First of all, it is only useable up until 1 meter sea level rise. Second, the Banjaard is located in a harsh wave climate, meaning it is hard to keep the sand in place. This means that most likely hard structures are needed to keep the islands in place. Third of all, the Scheldt is a river with significant sandhunger. This means that there is no guarantee the island, once placed will not erode straight away. Lastly, it is not a solution for SLR, only for dampening incoming waves.

Lessons learned

- **Letting nature do the work.** As mentioned before, by using Building with Nature, the majority of the work is done by nature. This potentially saves costs, and also leads to minimal disturbances of the current natural system. Additionally, by letting natural processes dominate the sedimentation, there is a hope that the island breakwaters will grow with SLR, thus providing protection for the foreseeable future.
- **Watching out for fresh water supply and salt-water intrusion.** In this plan, like other plans, special care is taken to store fresh drinking water in the dunes and to protect against salt-water intrusion. The way of protecting against salt-water intrusion is different than the gel sluices proposed by Leo van Gelder. The reason for that is that a fresh-salt gradient is beneficial for fish migration.

Presentation 5: Ronald Waterman
Integrated Coast & Delta Policy via Building with Nature & Aquapuncture
Small summary: Ronald Waterman introduced the concepts of Building with Nature and Aquapuncture in this presentation. Building with Nature is a way of implementing soft measures instead of hard measures. This way of working gives more room for nature and recreation among other functions, which in turn increases liveability and the local biodiversity. Additionally, by allowing nature to do the work it can save money and effort. A same sort of premis is behind Aquapuncture, where soft measures are used to increase the natural functioning of the inland water systems while keeping or even improving economic functioning.

Lessons learned

- **Small adaptations at a time.** One caveat of building with nature is that nature often does not deal well with large and sudden changes. One lesson to learn from this is that whenever nature is involved, splitting up a larger plan into smaller adaptations at a time results in much smoother implementation in the area. In other words, the surroundings like nature and the local community can more easily adapt to the changes that occur due to an implemented plan.
- **Good plans have their roots in the past and point towards the future.** Ronald Waterman means by this that to get to a future desirable situation, one should look to the way things used to be and why they were this way. The past often gives hints on the way a natural system tries to balance itself. An example of how this can be done was given by Waterman who based the forming of new sand dune ridges on their orientation in the past.
- **Allow nature to do the work.** Another benefit of building with nature is that it lets the natural forces take over. This means that less effort has to be put into getting to a certain desirable situation. Next to reducing costs, nature doing the work means it is not interrupted as much. This in turn allows the local ecology to mature and become more resilient. An example where these previous two benefits really shine is Marcel Stive's Sand Engine (presentation 2).

Presentation 6: Han Vrijling
Introduction to the problem of sea level rise
Small summary: Models indicate that climate change causes higher discharges, more extreme storms and sea level rise. Together with sinking soil this could be extremely problematic. Han Vrijling poses, however, that the observed SLR has not reached the expected height, but is considerably lower. This makes it difficult to design for climate change since it is easy to overdimension future plans. He also mentioned that while adaptable infrastructure is an attractive idea, it is difficult to apply in designs as the future is uncertain. Problems may change in the future, (partially) rendering adaptable infrastructure obsolete. In combination with the use of a discount rate, potential future savings have to be discounted which results in the creation of adaptable infrastructure being very expensive. Adding onto adaptable infrastructure, when planning for the future problems can also arise if the technical lifespan is too large. This can conflict with the efficiency of new designs and new building materials that are created in the future, meaning the structure can't adapt to the changing times

Lessons learned

- **Watch for the investment and maintenance costs.** The costs is something that came back in every presentation. There are plans like for instance the plan of Leo van Gelder(creating inlets in dunes). This plan is cheap as nature does most of the work, also no/little maintenance is needed. On the other hand you have the plan of Dick Butijn and Will Born (Haakse seadike). This plan has very large investment and maintenance costs.
- **The future is uncertain and costs money through a discount rate.** Tied closely to investment costs is the discount rate, as pointed out by Han Vrijling. This discount rate is used to take into account the depreciating value of infrastructure over time. It states that the same amount of money is less valuable in the future due to inflation. This means that whenever possible, infrastructure investments should be pushed to the future. This helps to counter the depreciation.
- **It is important to stay critical.** Han Vrijling was quite critical of the IPCC reports and other model-based predictions. While legions of scientists are behind this research, it is always important to stay

critical whenever reviewing a potential plan. By staying critical and keeping an open mind of what is possible potential faults in reasoning can be identified, and the argument for a potential plan strengthened.

Presentation 7: Dick Butijn and Wil Borm

How to protect the Netherlands and Northwestern Europe against climate change

Small summary:

Dick Butijn and Wil Borm are working together on an idea called the Haakse Seadike. The idea is to construct a seadike in phases in front of the Dutch coast, which can potentially be lengthened by neighboring countries. This plan is adaptable and phaseable, starting with protecting the harbor of Rotterdam and Zeeland and using Building with Nature to build outwards. It is also sustainable for the Haakse Seadike to work up to more than 10 meters of SLR. Adittionally, there will be no salt water intrusion, and there is potential for energy lakes as done currently by Delta21. A seadike off the Dutch coast also provides extra room for nature, although the lack of salt water and tides will mean that the nature created here is very different from the nature that was previously here. Other potential problems are that a seadike is a very expensive project that takes a long time to build, and it can be very hard to convince all the different stakeholders due to this. A long construction time also means that when dealing with a quick acceleration of SLR, one might already be too late.

Lessons learned

- **Watching the operational & the maintenance costs.** The operational costs is something that was mentioned especially during the presentation of Dick Butijn and Will Borm. In their plan they use high pumping capacity, which needs a high amount of energy and thus could potentially lead to high operational costs. However, with the use of energy lakes these costs could be brought down.
- **Being aware of choice lock-in.** After building a seadike like proposed, the potential to switch to other plans is drastically cut. This is because a seadike is a radical change, which is hard to turn back. Being stuck in a situation after having made a choice like this is also called choice lock-in. Since the Haakse seadike will work for more than 10 meters of SLR this is not necessarily a problem, but it is definitely something to look out for when creating a cohesive flood mitigation strategy.
- **Transitioning between plans within a pathway.** When designing an adaptive pathway, it is important that there is a smooth transition between different plans. This means knowing when to start construction, and being prepared by having investments and government approval ready. If this is not the case, there is an possibility that some of the plans in a pathway are realised too late. In the case of the Haakse Seadike, which is an expensive plan as well as having a long construction time, not watching out for these transition periods could potentially result in a lack of proper coastal protection.
- **Matching a plan with the SLR as well as possible.** Overdimensioning, or building something that is unnecessary for the current SLR, can be a big problem when building coastal protections. This was also mentioned by Han Vrijling in his presentation. The Haakse seadike is built in different phases. A new phase is only realised when a certain sea level is reached. In this way, overdimensioning can be prevented, and the plan can adapt to the actual SLR.
- **Creating economic opportunities.** While the main goal of all these plans is protection of the Netherlands against flooding, looking at optimizing on opportunities within this main goal can be very helpful. The Haakse Seadike has the potential for creating a lot of these economic opportunities. This is done by creating new space for floating cities behind the seadike, the ability for an airport in the sea as well as an harbour extension. Additionally, creating energy storage lakes can prove to be an economic opportunity as well.
- **Resisting salt-water intrusion and creating fresh water storage.** Salt-water intrusion can cause huge agricultural damage and contamination of the fresh drinking water. When using a seadike, fresh water lakes form behind it, as there is no direct connection with the ocean. The fresh water from rivers is used for the energy storage lakes as well, which further resists salt-water intrusion due to seepage.

Presentation 8: Jos Timmermans

Transform by Design - New grand old masters of Dutch hydraulic engineering

Small summary: Jos Timmermans' presentation was mainly about the change of the watermasters from old to new, as well as the drivers for this change. One important thing he mentioned was that often in real-life situation it is very difficult to detect the real problem, this often leads to the need of constructing the problem at the same time as its solution. The process he suggests for situations like this uses three paradigms: Engineering, Governance and Spatial Design. The engineering paradigm shows what is technically possible according to the laws of nature, while the governance paradigm tries to clarify what is possible according to the "locally constructed laws of social systems". Finally, spatial design is meant to look at how these two last paradigms might change in the future. By keeping in line with these three paradigms, it is possible to both identify the problem and look at potential solutions at the same time. Jos also mentioned that there are two types of change: Incremental and Transformative. Incremental change requires small changes within the current system. In flood risk mitigation, this can be seen as continuously strengthening dikes, or placing more coastal defenses. Transformational change requires the shifting of the way things have been traditionally done. In flood risk mitigation this could for example be the creation of floating cities, or a large seadike around the Netherlands.

Lessons learned

- **Complex problems require experts to communicate.** One thing Jos described was the shift in the way current watermasters create new protections versus the old watermasters. The current way of dealing with complex problems is by using an integrated approach. This means that many different experts are required to communicate and agree on the best possible solution. This is different than what was done in the times of Johan van Veen who, while brilliant, was considered an einzelganger in his time. This means that the communication between, and incorporation of as many different experts as possible is crucial in optimizing a plan.
- **Incremental versus transformative change for protecting against SLR.** Jos also talked about the importance of considering incremental versus transformative change. This can be done by for example building up a plan out of phases, or getting started on the first steps of transformative change while still incrementally increasing protection. This can prevent the possibility that transformative change is not realized in time, which would mean an increase of flood risk. It could also prevent the risk of transformative change having to happen suddenly. Such an abrupt disturbance could be harder to adapt to by society.

B Appendix: Plans from the brainstorm session

In the first week of the Multi Disciplinary Project, the group members held a brainstorming session. The walls of the room where the brainstorming session was held were covered with various floodprotection plans. The focus of these plans is the flood protection of the south-west of the Netherlands that were co-published by Deltares. Together with some students who participated in a minor, three groups of three people each were formed. The assignment was that the groups would walk along the published plans and in this way absorb the most important elements of these. After this session, the groups focused on creating a new plan consisting of aspects of the previously absorbed plans. The result of this brainstorming about plans to protect the South-West part of the Netherlands resulted in three plans which were quite different from each other. The plans are illustrated and explained below.

B.1 Plan 1 Waterworld

The first plan was creating a Waterworld with flooding houses protected by wave breakers. This Waterworld would arise when it is no longer profitable to make the water outside the land. In this case, the land moves with the sea water level so that the people can still live safely. You don't fight against the water, you go with the water. The Netherlands is currently small, which means that the space for building houses is also small. The Waterworld frees up a lot of space, so that building space no longer has to be a problem. This water world is also adaptable in keeping up with the water level of the sea. An impression of " Waterworld ", can be seen in figure 23.

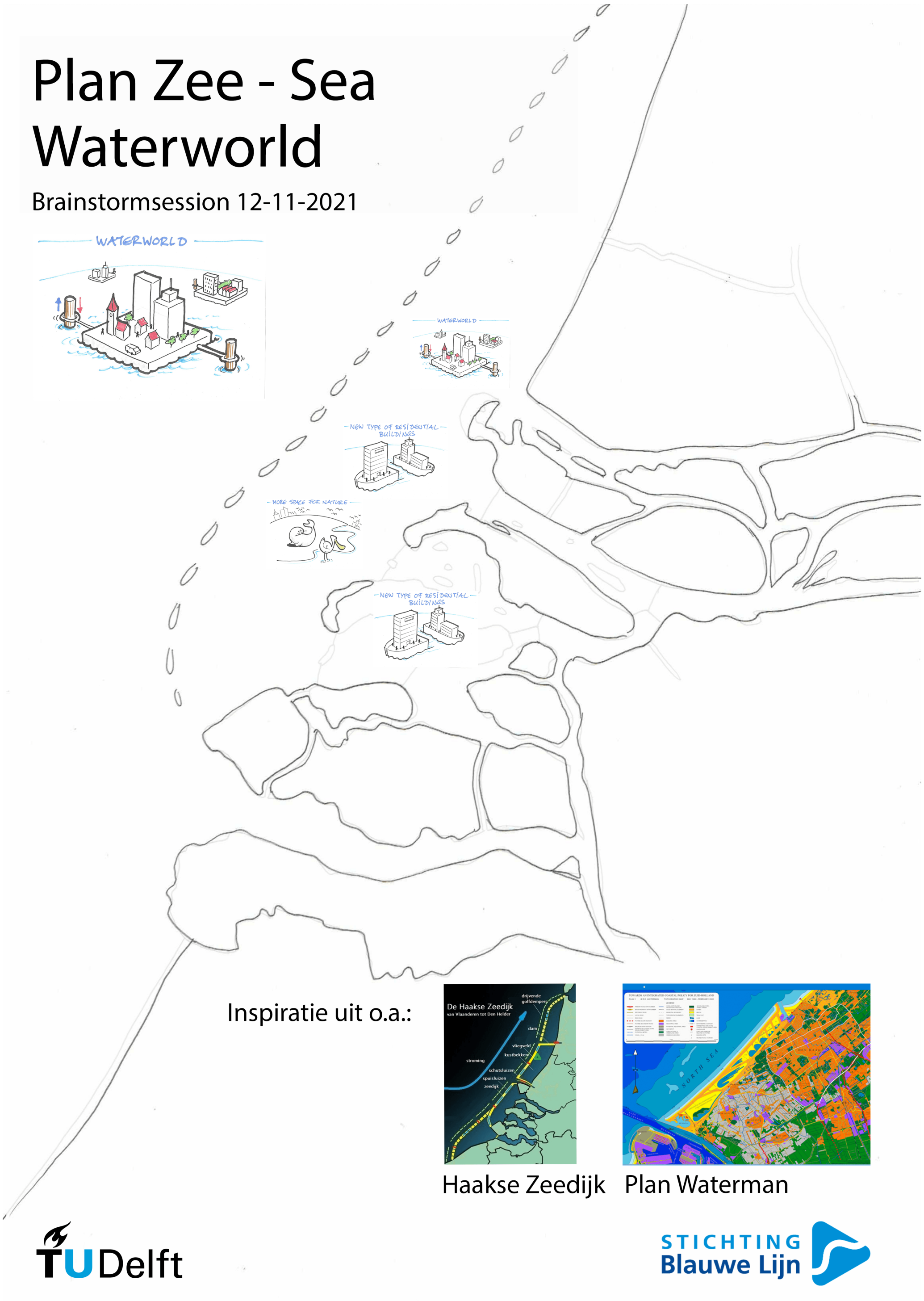

Figure 23: Plan 1 Waterworld

B.2 Plan 2 Building with Cities

The second plan was to relocate the harbour of Rotterdam further offshore and create building with city houses at the old port, while reinforcing the dikes. To keep Rotterdam and its port safe against rising sea levels, it is important to look at what the city itself has to offer. The city consists of many houses and buildings. This plan looks at the applicability of houses as multi functional flood protection. Just as the city wall used to protect the city against scum, the outer houses of Rotterdam do the same but then against the sea water. In this way, the city protects itself against sea level rise with its own houses. An impression of "Building with cities", can be seen in figure 24.

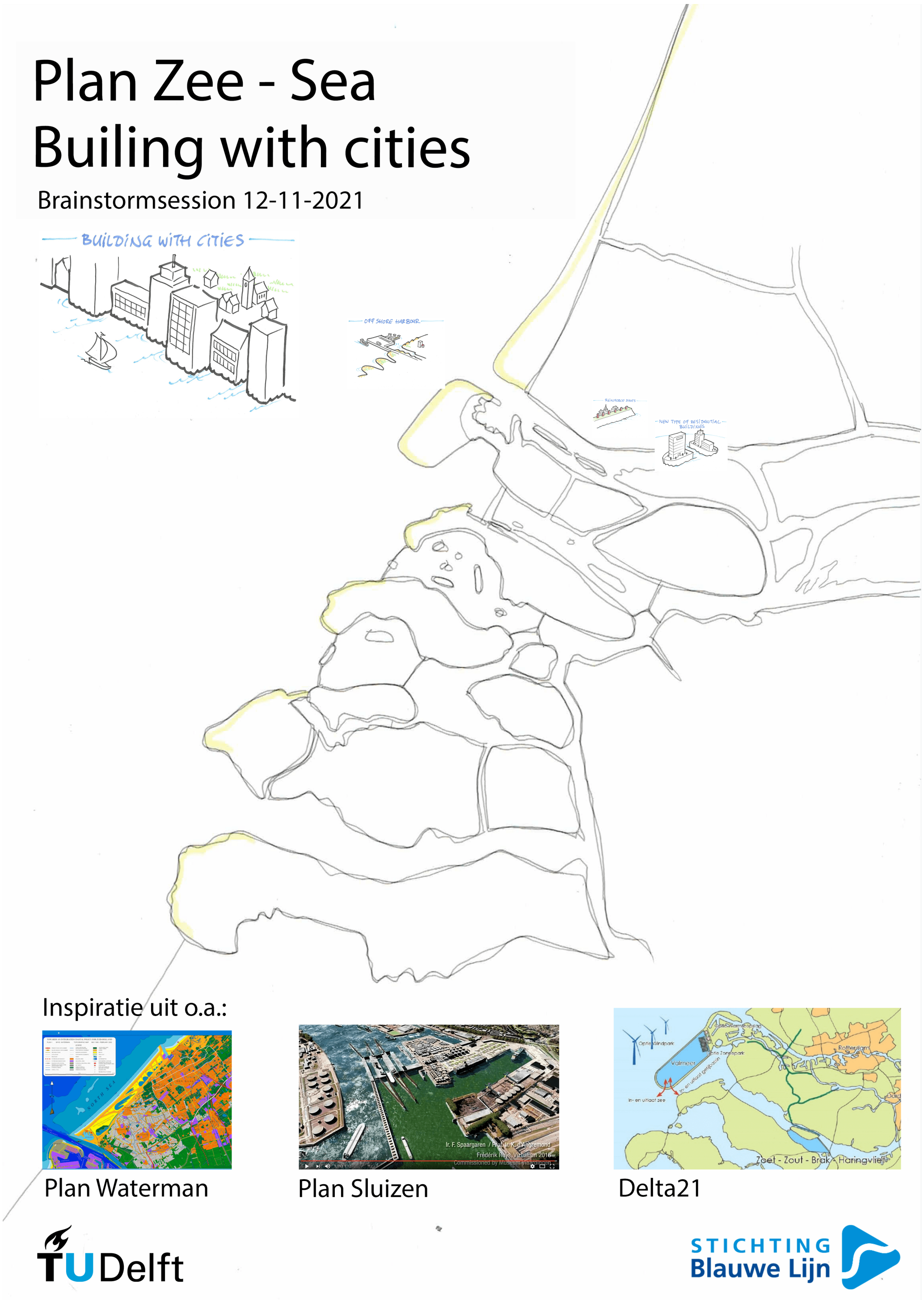

Figure 24: Plan 2 Building with Cities

B.3 Plan 3 New Zeeland in combination with inland dike heightening

The third plan was inspired by build with nature and the 'Verlandingsplan'. The intention of this plan is to ensure that the Netherlands is prepared for a considerably rising sea level. To increase robustness, the idea is to move the current Zeeland with its estuary outwards and so to create a New Zeeland. The old Zeeland will be closed off from the sea. With its sediment transport coming from the south, nature will enforce this flood defence. The dikes of the inland rivers and channels that are connect to the open sea, will be heightened so that any peak discharge from Germany can quickly flow into the sea. No pump is involved, making this open system a robust system. An impression of "New Zeeland in combination with inland dike heightening", can been seen in figure 25.

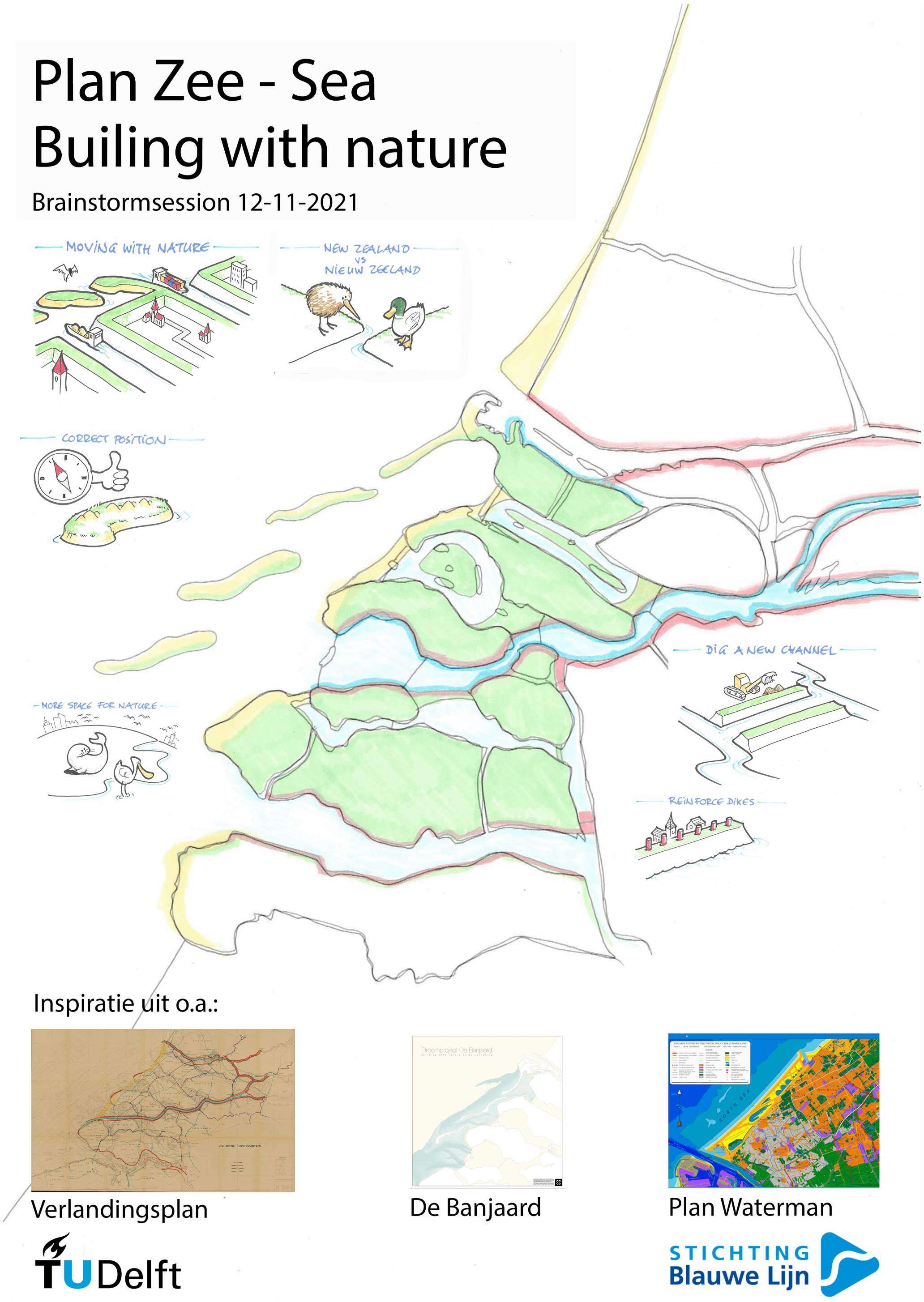

Figure 25: Plan 3 Building with Cities

C Appendix: Stakeholder analysis

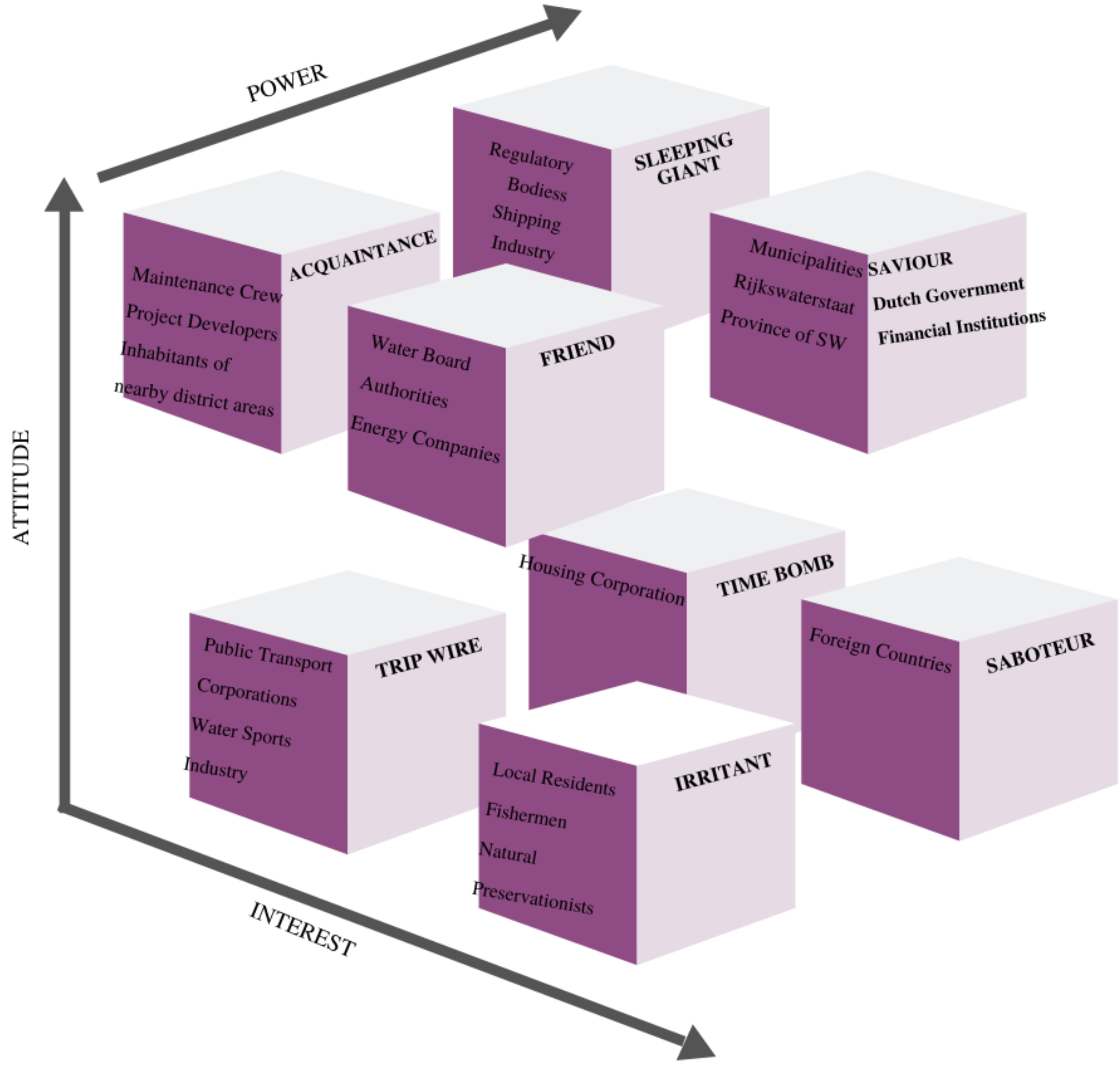

Figure 26: Project's Power vs Interest vs Attitude

According to a large-scale project, it's necessary to include a sufficient distinction between stakeholders. That gives an extra boost for clear and concise proposals from the decision makers. An effective tool is the Power vs Interest vs Attitude graph. By using those 3 parameters (power, interest, attitude), project developers could exert a critical look of which parties require most attention and how their ranking will be attributed based on that. The following points describe precisely the above-mentioned parameters:

Description Parameters

- **Power** Every party is characterized of each ability or capacity to influence other decisions depends on its strength and power of expressing their demands. That authority varies and has a huge importance when some remarkable changes could be happened around a project.

- **Interest** An entity can express his willingness for a certain project in accordance with its severity and influence on his/her position (such as economic, social etc.). Even if a project has a considerably social impact, some parties might have a limited interest and thus they done really care about its future feasibility.

- **Attitude** An entity's attitude could potentially be changed related to topic proposal. A way of introducing your actions and feeling could certainly impose some kind of purpose and reason beyond them. Seeking for the best outcome, a clear attitude establishment throughout a project (blocker, saboteur, positive etc.) is ultimately achieved.

  In case of the flood protective project, it was used a more developed terminology for stakeholders (based on their power, interest and attitude). The upcoming terms determine what kind a stakeholder could probably be induced:

- **Saviour** A powerful party with high interest and positive attitude (in other words influential, active and backer). His/her contribution is inevitably significant thus an detail inspection of what really desires needs to be established (attend his/her expectations).

- **Friend** A low powerful party with high interest and positive attitude (in other words insignificant, active and backer). His/her offer is slightly important but it's role is limited to a reliable and acceptable way of acting.

- **Saboteur** A powerful party with high interest and negative attitude (in other words influential, active and blocker). Even though his/her vitality is totally approved, the potential disputes and hindrances emerging for his/her involvement needs to be mitigated. Therefore, a strategy for eliminating his/her negative attitude should be a fundamentally topic.

- **Irritant** A low powerful party with high interest and negative attitude (in other words insignificant, active and blocker). It's engagement is important in order to avoid critical objections and damage through the project.

- **Sleeping Giant** A powerful party with low interest and positive attitude (in other words influential, passive and backer). His/her involvement seems really crucial in order to awake them and take an active participation on project process.

- **Acquaintance** A low powerful party with low interest and positive attitude (in other words insignificant, passive and backer). It's essential to keep those parties informed and discuss with them in sense of update project process.

- **Time Bomb** A powerful party with low interest and negative attitude (in other words influential, passive and blocker). It's necessary to hear their demands and understand what actually need from the project itself. That prevents their "explosion" and opposition during project's execution.

- **Trip Wire** A low powerful party with low interest and negative attitude (in other words insignificant, passive and blocker). It's necessary to hear their demands and understand what actually need from the project itself. That acknowledgement creates a project path without "stumble" issues.

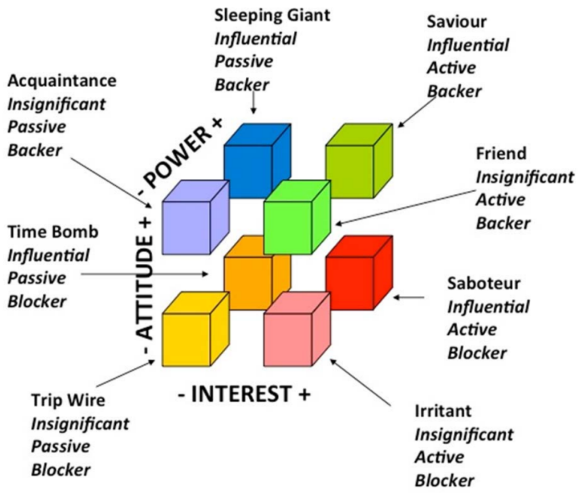

Figure 27: Power vs Interest vs Attitude

No	Name	Power	Interest	Attitude	Type	Involvement
1	Municipalities	High	High	Backer	Saviour	Empower
2	Regulatory bodies	High	Medium	Backer	Sleeping Giant	Consult
3	Maintenance Crew	Medium	Low	Backer	Acquaintance	Collaborate
4	Energy companies	Medium	Medium	Backer	Friend	Collaborate
5	Project developers	Medium	High	Backer	Acquaintance	Collaborate
6	Housing corporation	Medium	Medium	Blocker	Time Bomb	Inform
7	Local Residents	Low	High	Blocker	Irritant	Collaborate
8	Public transport Corporations	Low	Low	Backer	Tripwire	Involve
9	Water Sports Industry	Low	Medium	Blocker	Tripwire	Collaborate
10	Shipping Industry	Medium	Medium	Backer	Sleeping Giant	Inform
11	Water Board Authorities	High	Medium	Backer	Friend	Consult
12	Dutch Government	High	High	Backer	Saviour	Empower
13	Inhabitants of nearby district areas	Low	Low	Backer	Acquaintance	Inform
14	Fishermen	Low	High	Blocker	Irritant	Collaborate
15	Natural preservationists	Medium	High	Blocker	Irritant	Consult
16	Rijkswaterstaat	High	High	Backer	Saviour	Collaborate
17	Foreign Countries	High	High	Blocker	Saboteur	Collaborate
18	Financial Institutions	High	High	Backer	Saviour	Inform
19	Province of SW Holland	High	High	Backer	Saviour	Empower

Figure 28: Stakeholders in Flood Protective in SW Holland plan

Based on the different types of stakeholders related to their power, interest and attitude, it seems indispensable to clarify how the stakeholders in the flood protective case (in the Netherlands) are specified depends on the above 3 critical parameters:

- Parties with administrative authority (Municipality, Dutch Government and Province of SW Holland) are totally concerned as Savior. That introduces a key point of consideration (from project developers) due to their highly power, interest and attitude
- Parties with relatively high influence through a project (for instance Foreign Countries, Financial Institutions) could be called as Saboteur. Even if their huge power and interest is widely recognizable, the negative attitude could possible impose saboteur movements in order to prevent project's realization
- Parties with relatively high interest but negative attitude and lower or limited power (Fishermen, Natural Preservationists and Local Residents) are characterized as "Irritant". Their "irritation" behaviour needs to be apprehended so as to decide how to reverse it or to live with it
- Parties with administrative authority (regulatory bodies) and industrialize activities (shipping industry) can be called as sleeping giant (high/medium power, medium interest and positive attitude). Their involvement is too critical so project developers oblige to "wake them up"
- Parties with different business field (such as Maintenance Crew, Inhabitants of nearby district areas) can be called as Acquaintance. A good communication network will ensures acceptance and an optimum project result
- Parties with administrative authority (such as Water Board Authorities) and service providers (Energy Companies) can be called as Friend. Their high/medium power and semi-willingness of executed the project impose a "confident" role for a project success
- Parties with recreational activities (such as Water Sports Industry) and service providers (Public Transport Corporations) can be called as Tripwire. By understanding those sensitivities, it would ensure proper realization without "tripping up" issues
- Lastly, parties with service providers (Housing Corporation) can be called as Time bomb. By understanding those sensitivities, project developers deactivate their negative attitude and ensures project's feasibility

Stakeholder	Stakeholder Expectations
Municipalities	Area development, citizens satisfaction and economic welfare enhancement.
Regulatory bodies	Meeting the demands set by the project committee and appliance through the project realization
Maintenance Crew	Maintenance plan execution through the endless accessibility within the project site. Service well-operability and ongoing functionality
Energy companies	Primary focus into electrical elements installation. Accessibility through construction site and gains from productive energy
Project developers	Safety improvement and development further protective barriers (secure NL from external intrusion factors). Establishment well-oriented methods
Housing corporation	Main focus through housing prices and avoiding property owners' Illegal treatment
Local Residents	Lives Protection by ensuring sufficient incorporation within project's properties. "Their demands should be delivered"
Public Transports Corporations	Accessibility through construction site, adequate citizens transportation with safety and on time
Water Sports Industry	Basic target is offering recreational activities by attracting not only domestic but also international visitors. Profitability and public entertainment
Shipping Industry	Easy accessibility within waterways, commodities transportation with limited time delay. Profitability rising
Water Board Authorities	Dealing with crucial water management issues. Introducing methods for sufficient land protection (ensuring project feasibility)
Dutch Government	Project realization with citizens' satisfaction and commitment (increasing their popularity and ultimately votes collection). Be aware of potential warnings and difficulties (set up economic distribution plan)
Inhabitants of nearby district areas	Flood protective area with limited impacts from the new innovative structures (also anticipation for lower future housing expenses)
Fishermen	Ongoing fishing and continuity over years (without nature deterioration and biodiversity disturbance). Economic feasibility and profits which promote social welfare and advancement
Natural Preservationists	Natural protection, biodiversity escalation and lower human interventions as much as possible
Rijkswaterstaat	Guarantee of water development and provide technical specifications for effective water structures
Foreign Countries	Focusing on transparency and reliability within nation cooperation. Establishment of treaty agreement seems the most important element for proper/continuing mutual collaboration
Financial Institutions	Vital goal is to be reassured that their investment is being received in the future. Project developers (organization team) should be in able to return the money and meet their obligations
Province of SW Holland	Area development, citizens satisfaction and economic welfare enhancement (tourist attraction, popularity soaring)

Figure 29: Stakeholders Expectations

Stakeholders have an explicit participation throughout a project lifespan, in particular from the design phase mainly until the operational or maintenance stage. Mostly, if a project has a certain degree of complexity and possibly alterations might occur, it's seems necessary for the project developers to include their ambitions and concerns in accordance with their business or regulatory workout. Regardless of that, it appears interesting and vital to emphasize to every stakeholder itself by asking what they really want for that project and thus looking into their anticipations, arranging a stable/concrete decision making process. In case of the flood protective measurements in Netherlands, there are plenty of remarkable stakeholders that their viewpoints are considerably important:

- For instance, the local and governmental authorities (Municipalities, Province of SW Holland, Dutch Government) should focus more in citizens satisfaction, economic welfare and district advancement. Those characteristics imply the importance of taking care of the surroundings and simultaneously developing residents happiness and public enhancement. Since in democratic nations (including the Netherlands) elections are realized every 4 years, each government eagers to offer an exceptional service and acquiring public's endorsement. By doing this, public satisfaction will lead to re-elected process and thus constant community advancement

- Additionally, some parties who have a certain interest on that project (such as local residents, public transport corporations, inhabitants of nearby district areas) are really expressed their concerns about safety and security against external dangerous factors. In other words, local residents and inhabitants of nearby district areas require a safe and pleasant living environment and public transport corporations cares about safe ongoing transportation system.
- Following up the economic factor, a majority of stakeholders are mainly considered that aspect as a determinant parameter and one of the most significant project driver. For example, fishermen, financial institutions, housing corporations, water sports shipping industry demand an economic prosperity and sustainable community. According to that, their business will remain profitable and economic stability will be finally reached at all.
- It becomes clear that another important issue which stakeholders highly considered is the accessibility topic. Many of them, such as Shipping Industry, Maintenance Crew and Energy Companies are looking through free accessibly routes in order to expand their knowledge and expertise for social development.
- Lastly, parties like Rijkswaterstaat, Foreign Countries, Natural Preservationists and Regulatory bodies are searching for transparency and reliably outcome for the whole society. Any unstable and non-sufficient result could possibly derived from non-compliance with "open-book" demands (transparency) and inaccurate project feasibility (reliability).

No	Actor	Important Resources	Replaceability (high/low)	Resource Dependency (Low, moderate, high)	Critical Actor
1	Municipalities	Authority	Low	High	Yes
2	Regulatory Bodies	Authority	Low	High	Yes
3	Maintenance Crew	Facility Services	High	Moderate	No
4	Energy companies	Knowledge, Services	High	Low	No
5	Project developers	Experience, Knowledge, Process, Execution	Low	High	Yes
6	Housing corporation	Facility Services	Low	High	Yes
7	Local Residents	Knowledge	Low	Moderate	Yes
8	Public transport Corporations	Transportation Facilities	Low	Moderate	No
9	Water Sports Industry	Recreational Facilities	High	Moderate	No
10	Shipping Industry	Services	Low	High	Yes
11	Water Board Authorities	Knowledge, Authority	Low	High	Yes
12	Dutch Government	Authority	Low	High	Yes
13	Inhabitants of nearby district areas	Knowledge	High	Low	No
14	Fishermen	Knowledge, Services	Low	Low	No
15	Natural preservationists	Knowledge, Relations	Low	Low	No
16	Rijkswaterstaat	Law Authority	Low	High	Yes
17	Foreign Countries	Authority	Low	High	Yes
18	Financial Institutions	Knowledge, Service	High	High	Yes
19	Province of SW Holland	Authority	Low	High	Yes

Figure 30: Stakeholders Resource Dependency & Replaceability

Resources consist one of the most significant components in order to identify whether or not stakeholders shall be critical through a project. That becomes even more important when resources dependency influences a project's stability and feasibility over the following years. The power and social status are two crucial parameters which illustrate the resource strengthening ability of a stakeholder within an project environment. In case of the flood protective measurements in the Netherlands, the table above illustrates precisely some essential points to be mentioned:

- It's clearly demonstrated that the majority of stakeholders with relatively high power (for instance Rijkswaterstaat, Dutch Government, Province of SW Holland, Municipalities, Foreign Countries, Regulatory bodies, Water Board Authorities) show an incredible resource dependency with different actors. Their authorization ability indicates explicit connections with numerous disciplines (like industrial sector, educational sector, health system) and thus their resources are related accordingly with their development stage.
- Additionally, some parties with kind of services provisions (such as Financial Institutions, Shipping Industry, Housing Corporation) are concerned with high resource dependency due to the large network of suppliers incorporated through their business models. Therefore, their contribution seems necessary and critically as well

- Even though knowledge appears as a crucial characteristic for project success, usually is related with low entities resource dependency (such as energy companies, inhabitants of nearby district area, fishermen, natural preservationists).That includes low critically and thus limited categorization within the large number of involved stakeholders

- Lastly, it seems that even if some parties are still not replaceable their critical engagement is quite low. For example, service providers (maintenance crew, energy companies, water sports industry) and inhabitants of nearby district areas do not directly influence the project's outcome with their presence (even if project developers require their opinions and concerns for a final decision making).

Stakeholders	Political	Economical	Social	Technological	Legal	Environmental
Municipalities	✓	✓	✓			
Regulatory bodies					✓	
Maintenance Crew				✓		
Energy companies		✓		✓		
Project developers			✓	✓		
Housing corporation		✓			✓	
Local Residents			✓			
Public transport Corporations				✓		
Water Sports Industry		✓				
Shipping Industry		✓				
Water Board Authorities	✓					
Dutch Government	✓		✓			
Inhabitants of nearby district areas		✓	✓			
Fishermen		✓	✓			✓
Natural preservationists						✓
Rijkswaterstaat	✓					
Foreign Countries	✓					
Financial Institutions		✓				
Province of SW Holland	✓	✓	✓			

Figure 31: Stakeholders integration in PESTLE model

Since PESTLE model is totally applied as a tool to validate organisation's decisions based on its business aspirations and dreams, stakeholders ambitions should adhere to those 6 factors (Political, Economic, Social, Technological, Legal, Environmental). As had already been seen so far, stakeholders sensitivities drive the project's successful pathways and introduces certain kind of aspects which project developers should following up. In case of a flood protective topic (in the Netherlands), various interested parties (stakeholders) are attributed through PESTLE model factors for an optimum management and successful consolidation movements. Therefore, by the table above, it could easily be extracted that:

- Every kind of administrative authority (such as Municipalities, Water Board Authorities, Dutch Government, Rijkswaterstaat, Province of SW Holland, Foreign Countries) has a primary interest on the political side (due to administrative policies are applied from them). However, some authorities are expressed also their interests through different kind of sectors based on their additional business schedules (for instance, Province of SW Holland and Municipalities) looking into economical benefits and how to gained them within a certain project.

- addition, a majority of stakeholders focus especially through economical values and characteristics. More specifically, parties with clearly influence from economical factors (earnings, NPV, CBA etc) are Financial

Institutions, Shipping Industry. That happens due to their large power and impact from economic visibility and consistency around the globe (including the high range of investments). Additionally, other parties with similar or lower interest on economic sector are Water Sports Industry, Inhabitants of nearby district areas, Fishermen, and Housing Corporation, Energy Companies

- The technological interest lies more to parties with highly expertise personnel and a large-scale equipment based. For instance, Maintenance Crew, Energy Companies, Project Developers and Public Transport Corporations really delve into new ways of production and how to keep up with the latest technological advancements (leading to intensify research methodology for new state of the art techniques and applications)
- The legal interest is applying into authorities with highly motivated incentive to minimize discrimination and enhance a fairness and equality among people. In that case, regulatory bodies and housing corporations are explicitly involved into that important subjects (justice and equality)
- The social aspect is really triggered by multiple parties (such as Municipalities, Local Residents, Dutch Government, Fishermen etc.) which eagerness is driven by mutual consideration and appreciation of societal values (fairness, freedom, well-balanced goods allocation etc.) and how to serve them to a high rate
- Lastly, the environmental feature is undertaking completely from parties with huge environmental awareness (Natural Preservationists) and large impact into their activities (Fishermen)

D Appendix: Deltares wiki plans

As mentioned in chapter 7, twenty plans are taken into account from the Deltares Wiki, for each of the plans a short summary was written and if the plans met the requirements for selection, then an analyses was done for the to find the required knowledge for the applicable range.

Though requirements and other knowledge are gathered with utmost precision, not all data could be verified. So some data is based on the knowledge of the authors, the authors can therefore not guarantee the validity of the information found here.

D.1 Protected closed

A: Plan Emergo - Plan Emergo

A chain of islands in front of the coast of the south and the north of Holland provides protection of the old coast against waves. The lagoon that arises will result in a lot of biodiversity. This plan reduces the incoming wave height en shortens the incoming wave length. However the water can still flow around the islands, so for protecting against the rising sea level this won't the best solution.

Requirements:

- *SLR:* ✗
- *Storm surge:* ✗
- *Wave load:* ✓

B: Verstuiving in de duinen - Sand-drift in the dunes

With the help of grooves in the dunes, passing sand will transport itself to the underlying dunes which result in a natural growth of the dunes. The goal of this project is to create an automatic process of growth of a natural flood defence barrier like the dunes in the south-west of the Netherlands. (Arens et al., 2007)

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* The process for this plan is a relative easy process of digging a grove, the construction time is estimated to be one year.
- *Functional life time:* The functional life time is around 10 years as indicate by Arens et al. (2007).
- *SLR resistance:* The SLR resistance is a bit more uncertain due to the fact that the plan is mostly focused on bringing biodiversity back. Also this plan brings sand in the dune in the horizontal (up until 300 m) not as much in the vertical Deltares (2021). Therefore it is estimated to resist around 0.5 m.

C: Kunstriffen - Artificial reefs

Artificial reefs in front of the coast of the Netherlands will dampen the energy produced by the waves. Large floating tubes which are anchored to the bottom and perpendicularly to the wave direction will reduce the height of the waves which will result in lower waves when they reach the coast.

Requirements:

- *SLR:* ✗
- *Storm surge:* ✗
- *Wave load:* ✓

D: Deltadijk / Terpendijk / Klimaatdijk - Terpdike
Dikes in the hinterland of the Netherlands will be raised and widened to a width of 300 meters, so called mounds(terpen in Dutch). After that, houses and buildings are placed on it, so that the dike offers both protection and residential space.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* The required sand supply for this project is about 50 years Deltares (2021), therefore the construction time is estimated to be 50 years as well. The lead time however will be longer due to the social and political involvement as existing structures have to be demolished.
- *Functional life time:* This dike has the maximum functional life time of 100 years, which can be extended if well maintained and renovated.
- *SLR resistance:* The height of the dikes can be raised any need because of the weight of the dike, so the SLR resistance is set to be one till five meters.

E: Plan Sluizen - Plan locks
The rivers and the Zeeuwse Delta will be isolated permanently from the tide which results, so SLR will not influence the river, that ways the dikes and the quays don't have to be raised. However large pumps will be needed to pump out the water of the rivers in the sea.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* The current biggest sluice in the world in IJmuiden had a construction time of 6 years, therefore this sluice is estimated to have a construction time of 10 years per sluice. (*Nieuwe Zeesluis ijmuiden*, 2021)
- *Functional life time:* The functional life time for sluices is around 100 year.
- *SLR resistance:* The report of Borm et al. mentions a height difference of 0.85 meters between the sea and the rivers.

D.2 Protected open

F: Haakse Zeedijk - Haakse Sea-dike
Plan Haakse Sea-dike is a large dike in front of the coast of the Netherlands, with locks in it. It starts in Den Helder and runs to Walcheren. This dike protects the coast and the hinterland against the hydraulic loads. Between the dike and the old coast arise lagoons that host biodiversity. Harbours are still able to let in and out ships with the help of locks and water from the rivers will be pumped out in the sea. This plan is part of a bigger plan to finally cover also the coast of France to Denmark.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* The first part of the Haakse Zeedijk that covers the south west of the Netherlands is estimated to be finished in 40 years Deltares (2021).
- *Functional life time:* The dike has a maximum functional life time of 100 years, which can be extended if well maintained and renovated.
- *SLR resistance:* The Haakse zeedijk is estimated to resist a SLR of 5m, however this could be more by nourishment of the dune. With extreme high water from the river the water between the dike and the mainland can rise 2.5 m van den Haak (2020).

G: Dijkstad - Building with the City
Buildings will function as a flood water defence with the help of the first and second floor of each building. This will result in cities protecting themselves with their own buildings in coastal areas in the south-west of the Netherlands.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* Building a row of houses that has to withstand higher water levels in the river requires a high precision so a relative high construction time of 20 year is assumed. This is for smaller parts of the Southwest of the Netherlands.
- *Functional life time:* Based on the life time of concrete and reasoning that it has to with stand high loads the life time is set on 75 years.
- *SLR resistance:* Using buildings as flood defences means that you are building in a city, so to preserve the view of the city 1-3 meters seems most reasonable.

H: Ecobeach
With the help of natural sedimentation of the beach, a wider and broader beach can be created. This will happen with the help of tubes that are equally spreaded with a distance of 100 meter. The tubes do drain the water more quickly and so the beach will dry up better. This results in a quicker recovery of the beach. See figure 32

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* One year, because of the relative easy principal of just installing tubes in the beach. However for the effect to take place it takes 5-10 years.
- *Functional life time:* Plastic tubes do not erode easily so it could easily reach an life time of 100 years.
- *SLR resistance:* The dunes increas by 3 -5 meter as indicate by Ekkelenkamp, so a SLR resistance of 3 meter is assumed.

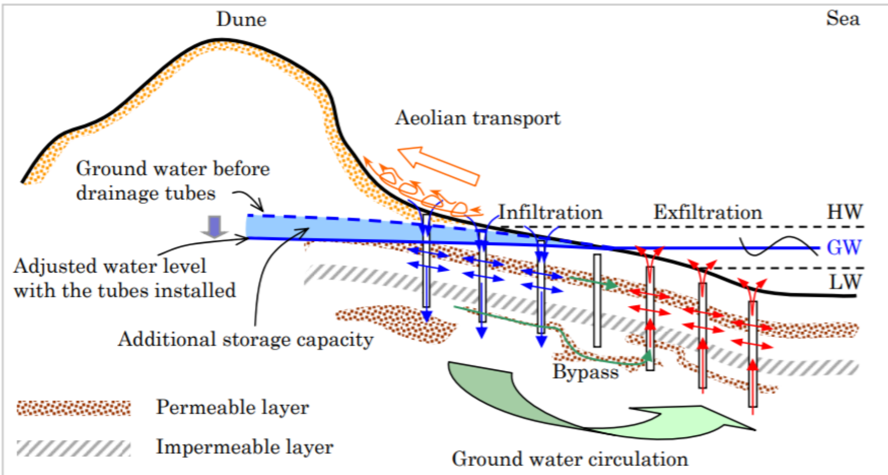

Figure 32: Eco beach (Deltares, 2021)

I: Dynamisch handhaven kustlijn en kustfundament - Dynamic maintaining coastline and coastal foundation

The coast of the Netherlands is currently maintained using nourishment. This results in protection of the hinterland against flood but the downside of it is that it takes a lot of effort each year.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* A couple months is the estimated construction time, but with increasing SLR this might become a year.
- *Functional life time:* Nourishment is currently once every 3 to 5 years (Appendix A), but with SLR this has to be more often. The functional life time of this plan is estimated to be 50 years.
- *SLR resistance:* This is adaptable to the SLR, however it depends on the amount of sand that is available. Currently the SLR is 20 cm per 100 years, which is 12 million cubic meter sand per year that is needed. For 85 cm per century means that 59 million cubic meter sand per year needed Deltares (2021).

J: Eiland voor één seizoen - Island for one season

Building an island off the coast to maintain the coastline instead of spreading it (plan I) to create leisure opportunities. The island will have a diameter of 500 meter and will rise 1,5 meter above the average high water level. 1,5 million cubic meter is needed.
Using this to experiment building islands in the North sea while also given insight in the sand transport along the Dutch coast. After a season the island will partially disappear and can be nourished the next summerDeltares (2021).

Requirements:

- *SLR:* ✗
- *Storm surge:* ✗
- *Wave load:* ✓

D.3 Moving seawards

K: Verbrede Kust - Broadening the Coast

With the large demand on houses and living space, the idea is to add an extra strip of coast in front of the old coast of Holland. This extra strip will be raised in order to prevent flooding and after that it will generate a lot of space to construct houses and buildings. (Kuiper et al., 2007)

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* The Deltares wiki mentioned 25 years. (Deltares, 2021)
- *Functional life time:* 50 Years, but is unsure due to the fact that with an increasing SLR it will also increase the malnourishment of the beaches, so it is hard to say how well the broadened coast can be maintained. Therefore sand nourishment is needed every couple years.
- *SLR resistance:* The broadening of the coast plan also increases the height of the beach which makes it SLR resistance. The amount of sand pilled up at the eco beach is similar as it increase sedimentation transport, so 3 meter seems a reasonable assumption.

L: Plan Waterman

The goal of this plan is to create a natural barrier of soft materials which is integrated with the old coast which protects the hinterland of the Netherlands against floodings. This natural barrier will grow with the help of the sediment transport along the coast with the direction from south to north.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* 25 Years as indicate on the Deltares wikiDeltares (2021).
- *Functional life time:* 50 Years, but is unsure due to the fact that with an increasing SLR it will also increase the malnourishment of the beaches, so it is hard to say how well the broadened coast can be maintained. Therefore sand nourishment is needed every couple years.
- *SLR resistance:* Functions are quite similar to the Broadened coast as it increase sedimentation transport by air, so 3 meter seems a reasonable assumption.

M: Geleidelijke aangroei Hollandse en Zeeuwse kust - Gradual accretion of the Holland and Zeeland coast

With the help of an oversupply of mechanical suppletion of sand at the coast of the Netherlands the coast will start to expand. This results in a better protection of the hinterland of the Netherlands against flooding in the future, see figure 33

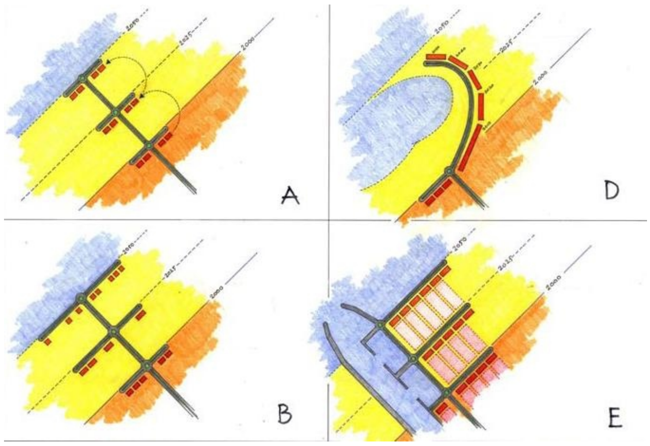

Figure 33: Gradual accretion of the Holland and Zeeland coast. Deltares (2021)

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* Similar to plan K: Broadening the coast and L: Plan Waterman, therefore 25 years.
- *Functional life time:* Similar to plan K and L, therefore 50 years, when maintained.
- *SLR resistance:* Similar to plan K and L, therefore protects around 3 to 5 meter SLR.

N: Evoluerende Blauwe Eilanden - Evolving blue islands
As illustrated in figure 34, this plan includes building island in front of the coast that work as wave barrier. The islands can also be used for housing, nature and recreating etc.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✗
- *Wave load:* ✗

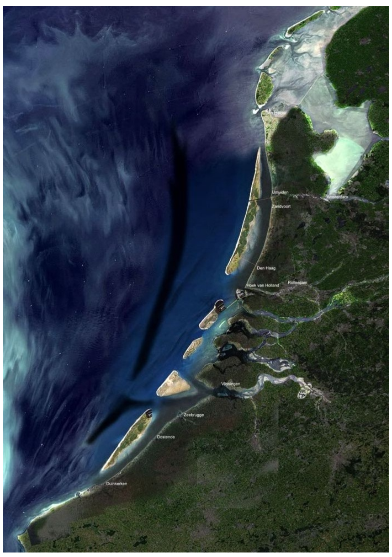

Figure 34: Evolving blue islandsDeltares (2021)

O: Brede kuststrook - Broadened coastal area
The idea of the Broadened coastal area provides a row of dunes that is located 3 kilometers out of the coast that will protect the south west of the Netherlands against floodings. The area between the old coast and the new dune row will be filled up with sand and will be used for construction of houses, nature and recreational purposes.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* 25 years, as the construction of the dunes can be realised relatively quick, the land behind the dunes however will take more time.
- *Functional life time:* It can be 100 years if well maintained.
- *SLR resistance:* The new land will be 4 meters above NAP, so the SLR resistance is 4 meter.

D.4 Moving with the sea

P: Getijdenstad - Tidal City
The tidal city is an idea of floating city in front of the coast. The city will be build on floating beams who are connected with hinges. Those anchored to a ground wall with a bridge to a floating foundation. The city will move with the tide and sedimentation will settle below the city causing the city nestle. The sandbanks that arise can help with land reclamation. (Juurlink, 2006)

Requirements:

- *SLR:* ✓
- *Storm surge:* ✗
- *Wave load:* ✗

Applicable range:

- *Construction time:* 100 years, as building a completely new city with infrastructure takes a lot of time.
- *Functional life time:* 100 years as a city will most like be well maintained.
- *SLR resistance:* Five meters, as it moves with the sea even though sedimentation settles, that does mean that the city becomes rigid, until a storm takes it away again.

Q: Terpen van baggerspecie - Mounds of dredged material
Many locations in the Netherlands are located below sea level. This means that when a flood occurs, these areas will run the risk of being submerged in water. In order to prevent that, the plan is to use dredged material to level up the locations where buildings and houses are built. This will prevent these locations from being harmed in the case of a flood.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* Uncertain

R: Drijvende Stad - Floating city
In a land where space for housing is scarce and where the land is at the same time threatened by a dangerously rising sea level, it can be seen as a possibility to implement a floating city. Floating cities that float with the rising sea level and provide a safe place to live can be a possibility to prevent the south west of the Netherlands from catastrophic events.

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✗

S: Nederland omhoog - Rising the Neterlands
Due to relative sea level rise in the Netherlands, the threat of flooding increases more and more. This plan has a purpose to level up the ground level of the Netherlands. Every time a new building or a group of houses are construction, first the ground level in this area will be leveled up. This will reduce the chance of flooding during the sea level rise. (Baan et al., 2004)

Requirements:

- *SLR:* ✓
- *Storm surge:* ✓
- *Wave load:* ✓

Applicable range:

- *Construction time:* 20 till 100 years as it takes quite a long time till enough new constructions are build for it to protect an entire city.
- *Functional life time:* 100 years after that house need to be rebuild
- *SLR resistance:* Five meters if the government set that as the standard for new building, but it will only be use for new constructions so it will not provide protectin for everyone.

T: Drijvende kassen - Floating greenhouses
Due to the lack of space in the Netherlands, there is a request for building locations, for like greenhouses, water storage, living and recreation. The next few years a lot of water storage needs to be constructed. By creating floating greenhouse that can go on top of the water storage a efficient and economical space is created.
Requirements:

- *SLR:* ✓
- *Storm surge:* ✗
- *Wave load:* ✗

E Appendix: Multi Criteria Analysis

As mentioned in chapter 9, The Multi Criteria Analysis is used to evaluate the different pathways of the DAPP. Before the MCA could be performed, it was important to obtain criteria. These criteria were taken from various sources from chapter 6 and subdivided into different categories in a table using the PESTLE method. The different sources are the stakeholder analysis, the old water master, the new water masters and a brainstorming session. This brainstorming session took place between the group members and with the help of everyone's expertise, this branch of the table was also completed. The table below is showing the different sources from chapter 6.

Catagorizing criteria
characteristics from old watermasters: *presentation of Henk-Jan verhagen(Johan van Veen, Cornelis Lely, etc.) *Marcel Stive - Sand Engine *Ronald Waterman - Building with Nature & Plan Waterman
characteristics from new watermaster(characteristics that are already under old watermasters not inlcuded) *Leo van Gelder - Inlet sand dunes & plan Spaargaren/sluices *Idco Duijnhouwer - de Banjaard *Han Vrijling - SLR *Dick Butijn & Wil Born - Haakse Zeedijks *Jos Timmermans - Transform by design
characteristics from stakeholders
charcateristics from student brainstorm session
Found criteria

Figure 35: categorizing the criteria, legend

The table below shows the categorizing the criteria, Political and Economic.

Political	Economic
Urgency (Cornelis Lely)	Good financial basis (Cornelis Lely)
Small adaptions a time -> easy implimentation(->phaseability) (Ronald Waterman)	
	Cheap by using nature(Leo van Gelder)
	Agricultural damage due to salt water intrusion(Leo van Gelder, Idco Duijnhouwer, Dick Butijn and Will Born)
	Creating economic opportunities(Dick Butijn and Will Borm)
	Costs(investment&maintanance)(Han Vrijling)
	Use of pumps -> expensive (Dick Butijn and Will Borm)
Transparancy	Profitability
Keep citizens satisfied during & after realisation (getting their votes in future election process)	Economic welfare
	Accessibly waterways(low economical damage as a result of the actions)
	Maintanance costs
Good integration into government policy	Creating economic growth
Constant political commitment & active participation	Social welfare equal distribution
Fast realisation time (general)	
Criteria: *good phaseability: small adaptations a time -> easy political implementation *fast realisation time of used actions -> easy to fit in during the 4 years of active government (no/little overlap between different reigns(="regeerperiodes")	Criteria: *limited costs actions (investment & maintenance of the actions) *creating economic opportunities (earn money) -> like creating a flood defence(like broadening the shoreline) which also can be used for housing *limited economical damage as a result of the actions -> like for instance a port that is blocked, fisherman who are hindered or agricultural damage due to salt-water intrusion

Figure 36: categorizing the criteria, Political and Economic

The table below shows the categorizing the criteria, Social and Technological.

	Technological
Finding publicity (Johan van Veen)	Good technical basis(technical knowledge aqcuisition) (Johan van Veen)
	Experts should fully agree (expert consensus) (Cornelis Lely)
	Coherence between big plans(->time adaptability?) (Johan van Veen)
Fresh (drinking) water storage(Leo van Gelder, Idco Duijnhouwer, Dick Butijn and Will Born)	Coherence between actions within pathway(Jos Timmermans & Dick Butijn and Will Borm)
Salt-water intrusion(contamites drinking water) (Leo van Gelder, Idco Duijnhouwer, Dick Butijn and Will Born)	
	Reliability
ıctions on the citizens	
Transparency	
ıation for the citizens	Robustness of the system
akeholders during the project	Use of advanced technological equipment (policies, materials, personnel)
stribution	Removabilty when it gets outdated (maybe it is more technological), because that is an issue with the delta works
Free & unlimited access through public administrative plans via online/street advertisments campaings (including insights based on predefined budget, time execution period, financial insitutions (as sponsors))	
Criteria: *limited negative impact of the actions on the citizens ->so no: visual pollution(blocked view to the sea for instance(huge seadike around houses for instance), reduced accesibility(when you break down the "Haringvlietdam", the accesability of the area is reduced), etc. *create natural and recreational benefits for the area -> create: public natural area's, recreational lakes, intertidal area's for animals, etc.	Criteria: *good reliability of the system -> when 1 pump or part of the flooddefence fails, does the whole system fail? robustness of the system, trustworthy? *good coherence between actions within a pathway (time adaptability?) -> smooth transition between different actions *good removability -> when the system exceeds the functional lifetime, is it easy to remove? *functional lifetime actions matches properly with actual trend of the SLR -> risk of over or under dimensioning an action

Figure 37: categorizing the criteria, Social and Technological

The table below shows the categorizing the criteria, Legal and Environmental.

Legal	Environmental
Adhere to laws now and in the future (Cornelis Lely)	Multi-functional use of nature(use of eco-friendly methods) (Marcel Stive) Building with nature(use of eco-friendly methods) (Ronald Waterman) Creating new nature(use of eco-friendly methods) (Ronald Waterman)
Safety-> does the action meet the dutch safety standards when it is realised Meeting the demands set by the project commitee	Sustainability
Security	Realised project guarantees natural preservation
Follow the laws of employment Expropriation of people out of their living area	Limiting the amount of pollution (pollution of what? structural, atmospheric, both of them??) Domestic supplier chain support (encouranging lower fuels emissions during materials transportation time) Low emissions during construction biodiversity equilibrium (fish migration and other flora, possibility for nature development) Interference in the system
Criteria: *easy to implement actions following the european/dutch laws -> for instance haakse seadike need approval from the EU and GB, while other actions only need approval from the dutch laws *high safety during construction -> possible hazards during construction, for instance a closure dam, the last part that needs to be closure is complex due to high flow speeds in the last gab that is closed). rainbowing of sand to broading the beach is less complex/hazardous *high safety during users phase -> consequence of failure actions(difficult to determine because expertise is needed, so apply low weighting factor) *low expropriation (="onteigening") of citizens due to actions in the pathway	Criteria: *use of eco-friendly methods -> building with nature, multi-functional use of nature, creating new nature *low interference of actions in biodiversity equillibrium -> no/little interference in fish migration and other flora, possibility for nature development *limited emissions during construction(N2, CO2, etc.) ->haakse seadike really high emissions vs plan waterman really low emissions

Figure 38: categorizing the criteria, Legal and Environmental

After determining the correct criteria using the PESTLE method, the Multi Criteria Analysis was drawn up. With the help of this analysis, all pathways were assessed separately. The result is that each pathway was given a final grade. This grade was made up of different partial grades (per category), each with their own weight. In this way it is possible to make a judgment based on the MCA about the quality of each pathway and which category scores good or moderate per pathway. The tables below show the assessment of the MCA per pathway and its final grade which is build up out of the sub grades per criteria.

Pathway 1	***weight***	***grade 1***	***grade 2***	***grade 3***	***grade 4***	***grade 5***	***grade 6***	***grade per criteria***	***grade criteria group***
1.Political	**10**								7.1
criterium 1.1:**phaseability**	6	7	8	6	7	8	7	7.17	-
criterium 1.2:**fast realisation time**	4	7	8	5	6	8	8	7.00	-
2.Economic	**6**								6.47
criterium 2.1: **creating economic growth**	3	8	7	6	6	7	7	6.83	-
criterium 2.2: **limited economical damage**	2	7	7	7	6	8	7	7.00	-
criterium 2.3: **limited costs actions**	1	5	6	5	6	6	5	5.50	-
3.Social	**6**								5.89
criterium 3.1:**limited negative impact of the actions on the citizens**	4	6	5	4	5	7	6	5.50	-
criterium 3.2:**create natural and recreational benefits**	2	7	6	7	6	7	7	6.67	-
4.Technological	**10**								6.38
criterium 4.1: **good reliability of the system**	4	6	5	5	7	7	6	6.00	-
criterium 4.2: **functional lifetime actions matches properly with actual trend of the SLR**	3	5	6	7	6	5	6	5.83	-
criterium 4.3:**good removability**	2	5	6	7	7	5	6	6.00	-
criterium 4.4: **good coherence between actions**	1	7	8	6	9	7	7	7.33	-
5.Legal	**6**								6.39
criterium 5.1: **safety during users phase**	2	7	8	7	6	7	5	6.67	-
criterium 5.2:s**afety during constrution**	2	7	7	8	7	6	6	6.83	-
criterium 5.3:**easy to implement actions following the european/dutch laws**	1	4	5	6	5	6	4	5.00	-
citerium 5.4: **limited expropriation**	1	8	8	7	8	9	8	8.00	-
6.Environmental	5								6.67
criterium 6.1: **limited emissions**	2	6	7	6	8	8	7	7.00	-
criterium 6.2: **eco-friendly methods**	1.5	7	7	5	6	7	6	6.33	-
criterium 6.3:**biodiversity equillibrium**	1.5	7	7	7	5	7	7	6.67	-
Final grade pathway:	***6.53***								

Figure 39: Assessment of pathway 1

Pathway 2	weight	grade 1	grade 2	grade 3	grade 4	grade 5	grade 6	grade per criteria	grade criteria group
1.Political	**10**								7.03333
criterium 1.1:**phaseability**	6	8	7	8	7	7	6	7.17	-
criterium 1.2:**fast realisation time**	4	7	7	8	6	7	6	6.83	-
2.Economic	**6**								2.64
criterium 2.1: **creating economic growth**	3	8	7	6	7	7	8	7.17	-
criterium 2.2: **limited economical damage**	2	1	2	1	1	3	2	1.67	-
criterium 2.3: **limited costs actions**	1	2	2	1	3	1	2	1.83	-
3.Social	**6**								4.89
criterium 3.1:**limited negative impact of the actions on the citizens**	4	3	4	2	5	4	3	3.50	-
criterium 3.2:**create natural and recreational benefits**	2	7	8	9	8	7	7	7.67	-
4.Technological	**10**								7.88
criterium 4.1: **good reliability of the system**	4	9	8	9	8	7	9	8.33	-
criterium 4.2: **functional lifetime actions matches properly with actual trend of the SLR**	3	8	9	8	8	9	7	8.17	-
criterium 4.3:**good removability**	2	8	9	7	9	9	7	8.17	-
criterium 4.4: **good coherence between actions**	1	8	7	8	6	7	6	7.00	-
5.Legal	**6**								6.81
criterium 5.1: **safety during users phase**	2	8	7	6	8	7	7	7.17	-
criterium 5.2:**safety during constrution**	2	8	8	7	8	9	7	7.83	-
criterium 5.3:**easy to implement actions following the european/dutch laws**	1	8	8	9	7	8	9	8.17	-
citerium 5.4: **limited expropriation**	1	1	2	2	1	3	1	1.67	-
6.Environmental	5								7.27
criterium 6.1: **limited emissions**	2	8	7	6	8	6	8	7.17	-
criterium 6.2: **eco-friendly methods**	1.5	7	8	8	6	7	9	7.50	-
criterium 6.3:**biodiversity equillibrium**	1.5	7	6	8	7	8	7	7.17	-
Final grade pathway:	***6.31***								

Figure 40: Assessment of pathway 2

Pathway 3	weight	grade 1	grade 2	grade 3	grade 4	grade 5	grade 6	grade per criteria	grade criteria group
1.Political	**10**								7.2
criterium 1.1:**phaseability**	6	8	9	8	8	7	6	7.67	-
criterium 1.2:**fast realisation time**	4	6	7	6	5	8	7	6.50	-
2.Economic	**6**								5.81
criterium 2.1: **creating economic growth**	3	7	6	7	8	7	7	7.00	-
criterium 2.2: **limited economical damage**	2	7	6	5	7	6	6	6.17	-
criterium 2.3: **limited costs actions**	1	5	4	6	4	5	4	4.67	-
3.Social	**6**								5.67
criterium 3.1:**limited negative impact of the actions on the citizens**	4	5	5	5	6	5	6	5.33	-
criterium 3.2:**create natural and recreational benefits**	2	6	6	7	8	5	6	6.33	-
4.Technological	**10**								7.42
criterium 4.1: **good reliability of the system**	4	8	7	7	9	8	9	8.00	-
criterium 4.2: **functional lifetime actions matches properly with actual trend of the SLR**	3	8	8	6	8	7	8	7.50	-
criterium 4.3:**good removability**	2	7	6	7	6	6	6	6.33	-
criterium 4.4: **good coherence between actions**	1	7	8	8	7	6	8	7.33	-
5.Legal	**6**								5.89
criterium 5.1: **safety during users phase**	2	7	6	7	6	8	7	6.83	-
criterium 5.2:**safety during constrution**	2	6	6	6	5	5	7	5.83	-
criterium 5.3:**easy to implement actions following the european/dutch laws**	1	4	5	5	3	3	5	4.17	-
citerium 5.4: **limited expropriation**	1	8	9	9	7	8	10	8.50	-
6.Environmental	5								5.65
criterium 6.1: **limited emissions**	2	7	6	5	8	7	7	6.67	-
criterium 6.2: **eco-friendly methods**	1.5	6	6	7	7	6	5	6.17	-
criterium 6.3:**biodiversity equillibrium**	1.5	4	3	6	5	4	5	4.50	-
Final grade pathway:	***6.48***								

Figure 41: Assessment of pathway 3

Pathway 4	weight	grade 1	grade 2	grade 3	grade 4	grade 5	grade 6	grade per criteria	grade criteria group
1.Political	**10**								4.06667
criterium 1.1:**phaseability**	6	3	5	4	4	3	3	3.67	-
criterium 1.2:**fast realisation time**	4	4	4	5	6	3	6	4.67	-
2.Economic	**6**								5.03
criterium 2.1: **creating economic growth**	3	3	5	5	3	3	6	4.17	-
criterium 2.2: **limited economical damage**	2	6	6	6	4	5	7	5.67	-
criterium 2.3: **limited costs actions**	1	4	3	3	5	6	6	4.50	-
3.Social	**6**								6.44
criterium 3.1:**limited negative impact of the actions on the citizens**	4	7	8	8	6	7	6	7.00	-
criterium 3.2:**create natural and recreational beneftis**	2	5	7	4	4	7	5	5.33	-
4.Technological	**10**								7.67
criterium 4.1: **good reliability of the system**	4	9	7	8	8	7	8	7.83	-
criterium 4.2: **functional lifetime actions matches properly with actual trend of the SLR**	3	8	8	8	7	7	7	7.50	-
criterium 4.3:**good removability**	2	9	8	8	8	9	7	8.17	-
criterium 4.4: **good coherence between actions**	1	8	8	7	7	7	6	7.17	-
5.Legal	**6**								7.19
criterium 5.1: **safety during users phase**	2	8	7	7	6	8	9	7.50	-
criterium 5.2:s**afety during constrution**	2	8	7	7	7	8	6	7.17	-
criterium 5.3:**easy to implement actions following the european/dutch laws**	1	7	7	8	6	8	7	7.17	-
citerium 5.4: **limited expropriation**	1	7	7	7	6	8	7	7.00	-
6.Environmental	5								6.63
criterium 6.1: **limited emissions**	2	6	5	5	7	4	4	5.17	-
criterium 6.2: **eco-friendly methods**	1.5	7	7	8	6	8	7	7.17	-
criterium 6.3:**biodiversity equillibrium**	1.5	7	6	8	8	8	7	7.33	-
Final grade pathway:	***6.1***								

Figure 42: Assessment of pathway 4

Pathway 5	weight	grade 1	grade 2	grade 3	grade 4	grade 5	grade 6	grade per criteria	grade criteria group
1.Political	**10**								3.63333
criterium 1.1:**phaseability**	6	4	5	5	4	4	3	4.17	-
criterium 1.2:**fast realisation time**	4	3	5	2	2	3	2	2.83	-
2.Economic	**6**								4.97
criterium 2.1: **creating economic growth**	3	6	6	7	5	6	5	5.83	-
criterium 2.2: **limited economical damage**	2	6	5	5	7	6	7	6.00	-
criterium 2.3: **limited costs actions**	1	3	3	4	2	4	2	3.00	-
3.Social	**6**								5.78
criterium 3.1:**limited negative impact of the actions on the citizens**	4	5	6	4	4	6	7	5.33	-
criterium 3.2:**create natural and recreational beneftis**	2	7	6	6	7	6	8	6.67	-
4.Technological	**10**								6.10
criterium 4.1: **good reliability of the system**	4	5	6	6	4	5	5	5.17	-
criterium 4.2: **functional lifetime actions matches properly with actual trend of the SLR**	3	8	9	8	7	8	7	7.83	-
criterium 4.3:**good removability**	2	4	5	3	4	6	5	4.50	-
criterium 4.4: **good coherence between actions**	1	8	8	8	9	7	7	7.83	-
5.Legal	**6**								6.25
criterium 5.1: **safety during users phase**	2	8	6	8	8	7	9	7.67	-
criterium 5.2:s**afety during constrution**	2	7	7	5	8	6	8	6.83	-
criterium 5.3:**easy to implement actions following the european/dutch laws**	1	4	6	3	5	4	4	4.33	-
citerium 5.4: **limited expropriation**	1	8	7	7	8	8	7	7.50	-
6.Environmental	5								4.45
criterium 6.1: **limited emissions**	2	5	5	4	6	5	6	5.17	-
criterium 6.2: **eco-friendly methods**	1.5	5	7	6	6	5	5	5.67	-
criterium 6.3:**biodiversity equillibrium**	1.5	3	3	4	2	4	2	3.00	-
Final grade pathway:	***5.15***								

Figure 43: Assessment of pathway 5

Pathway 6	*weight*	*grade 1*	*grade 2*	*grade 3*	*grade 4*	*grade 5*	*grade 6*	*grade per criteria*	*grade criteria group*
1.Political	**10**								3.6
criterium 1.1:**phaseability**	6	3	3	5	2	2	3	3.00	-
criterium 1.2:**fast realisation time**	4	4	5	3	5	6	4	4.50	-
2.Economic	**6**								6.78
criterium 2.1: **creating economic growth**	3	3	3	3	5	4	3	3.50	-
criterium 2.2: **limited economical damage**	2	8	9	7	8	8	9	8.17	-
criterium 2.3: **limited costs actions**	1	6	6	7	7	5	7	6.33	-
3.Social	**6**								6.22
criterium 3.1:**limited negative impact of the actions on the citizens**	4	7	8	5	6	7	8	6.83	-
criterium 3.2:**create natural and recreational beneftis**	2	5	6	5	4	4	6	5.00	-
4.Technological	**10**								8.28
criterium 4.1: **good reliability of the system**	4	9	8	8	10	7	9	8.50	-
criterium 4.2: **functional lifetime actions matches properly with actual trend of the SLR**	3	8	8	7	8	7	8	7.67	-
criterium 4.3:**good removability**	2	9	9	10	8	8	9	8.83	-
criterium 4.4: **good coherence between actions**	1	8	7	8	9	7	8	7.83	-
5.Legal	**6**								7.72
criterium 5.1: **safety during users phase**	2	8	9	9	8	8	8	8.33	-
criterium 5.2:**safety during constrution**	2	8	7	8	9	8	8	8.00	-
criterium 5.3:**easy to implement actions following the european/dutch laws**	1	7	8	8	7	6	7	7.17	-
citerium 5.4: **limited expropriation**	1	8	7	9	7	7	8	7.67	-
6.Environmental	5								7.77
criterium 6.1: **limited emissions**	2	7	8	8	7	8	7	7.50	-
criterium 6.2: **eco-friendly methods**	1.5	7	6	8	6	7	7	6.83	-
criterium 6.3:**biodiversity equillibrium**	1.5	9	9	10	8	7	9	8.67	-
Final grade pathway:	***6.56***								

Figure 44: Assessment of pathway 6