Towards a safe and sustainable IJsseldelta

Strategic advice for Green Rivers to preserve biodiversity and ecosystem services while ensuring flood protection for the IJssel river area.

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Table of contents

1. Introduction

1.1 A Shift in Flood Protection Paradigm

Traditionally, the paradigm for flood protection policy in the Netherlands resulted in more dike construction and maintenance when dike rings did not comply to the existing protection standards (De Bruijn, De Bruijne & Ten Heuvelhof, 2015). These standards were based on risk and cost-benefit analysis, which considered both economic indicators as well as safety indicators of inhabitants in the dike rings (Nillesen & Kok, 2015). However, high water levels in 1993 and 1995, have caused flood experts to emphasise that this responsive dike strengthening strategy may not lead to more flood protection due to the impacts of climate change. Climate change impacts the Dutch deltas with increasing flood risks (Ministry of Infrastructure and Environment, 2018). Key consequences experts put forward as a result were: more rainfall in the upstream parts of rivers, gradual sinking of the Netherlands to even lower sea levels ('settlement'), and sea level rise, which made it harder to pump river water into the sea (De Bruijn et al., 2015).

According to the experts, solely constructing dikes poses the risk of increasing the *severity* of floods. Moreover, the standards insufficiently reflected the expected consequences of flooding, mainly related to the societal disruption, economic efficiency of investments, and in particular: the negative effects on spatial quality and environmental values which were not considered (Klijn, F., de Bruin, D., de Hoog, M. C., Jansen, S., & Sijmons, D. F., 2013); Visscher, 2018). Higher dikes to accommodate large volumes of water therefore became a risk in and on itself. Given the uncertainty in the impacts of climate change, and as a consequence, the extent to which standards are adapted to these impacts, a new paradigm was proposed by the Dutch cabinet: Room for the River (RfR).

Room for the River aims to manage higher water levels by giving the river more room, preventing further rise of water levels. It does this through a 'systems-approach', in which entire rivers and deltas are considered as one system with forward and backward feedback mechanisms (Vydra, 2019). There are different measures and techniques which can be applied to realize more room for the river, such as widening the riverbed, excavating floodplains, and constructing flood retention zones (Figure 1). These different configurations reflect adaptability and adjustment to different circumstances at each location close to rivers. Room for the River can therefore be seen as a shift from the traditional paradigm of anticipation to a paradigm of resilience, leading to the absorbance or "control" of disturbances, in this case high water levels and possible floods. It is an approach which accepts that floods may occur, but seeks to "exploit the advantages of flooding and mitigating the disadvantages" in different ways at different locations (Warner, Edelenbos & van Buuren, 2013).

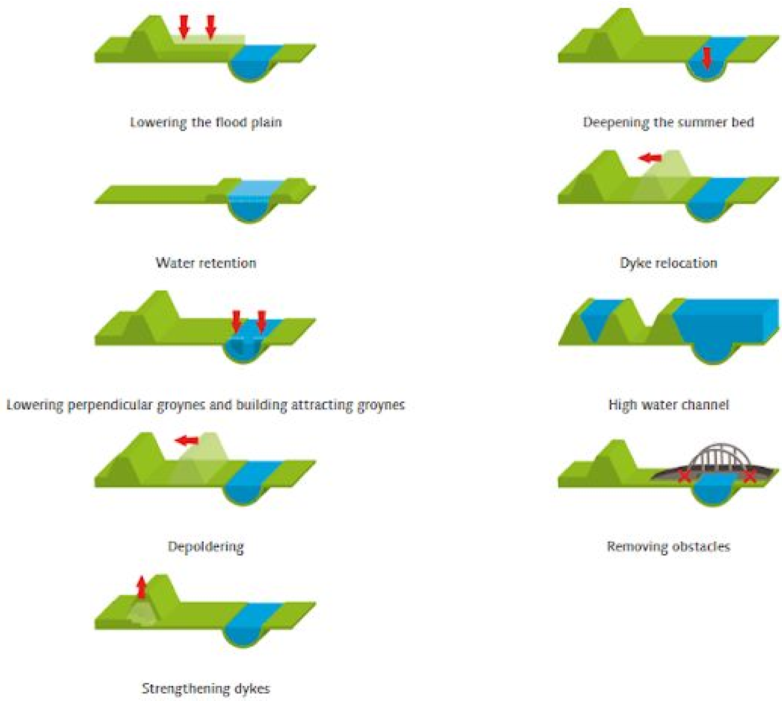

Figure 1. The different configurations for Room for the River (Room for the River, 2019).

1.2 Room for the River: the case of the IJssel River

The Netherlands has four major European rivers which flow to the sea, and along which projects for Room for the River can be carried out: the Rhine, Meuse, Schelde and Eems (De Bruijn et al., 2015). One of the branches of the Rhine is the river IJssel, in the Dutch provinces Gelderland and Overijssel. The high tides make the area prone to flooding, and therefore, there are five locations which have been taken into consideration by the Ministry of Infrastructure and Water Management for Room for the River: Doesburg, Cortenoever, Zutphen, Gorssel, and Deventer (Figure 2).

Three separate solutions are being considered for each of these important areas, in order to deal with the increasing flood risk. These solutions can be used complementary and can differ per location around the IJssel. *Creating room for the IJssel river*, by broadening the area can contribute not only to protecting the surrounding areas from flooding, but also to strengthening the spatial quality of the area. *Heightening the existing dikes* can aid in efficiënt usage of the river for transport, besides securing flood protection. Next to these protective measures, a third mitigation option is considered.

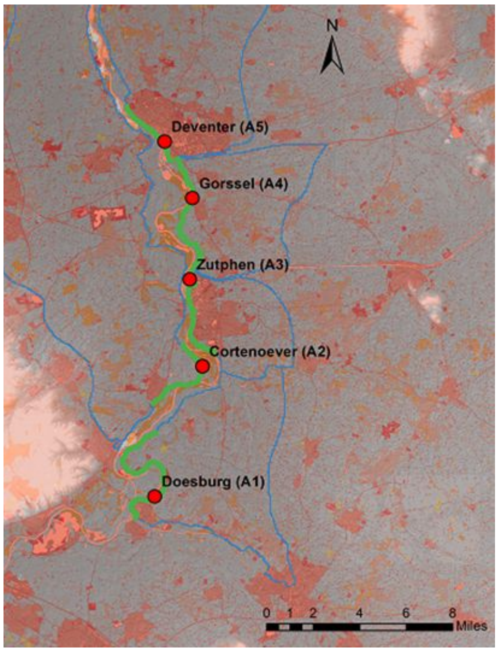

Figure 2. The different important locations along the IJssel (Ciullo, 2019).

Warning the population that is at risk of getting flooded before the actual flood takes place. This would lead to evacuation in order to lower the damage that is done to human life, but it could lead to economic damages in case of a false positive. This last policy has also been taken into consideration since 76 percent of Dutch citizens indicates that they are not prepared for a flood (Red Cross, 2018).

Room for the River does not only imply a shift in engineering from adaptation to resilience. Warner et al. (2013) also describe Room for the River as a shift from "vertical, top-down management to more egalitarian forms of multi-actor network governance". This implies that a broader range of stakeholders are involved (Figure 3).

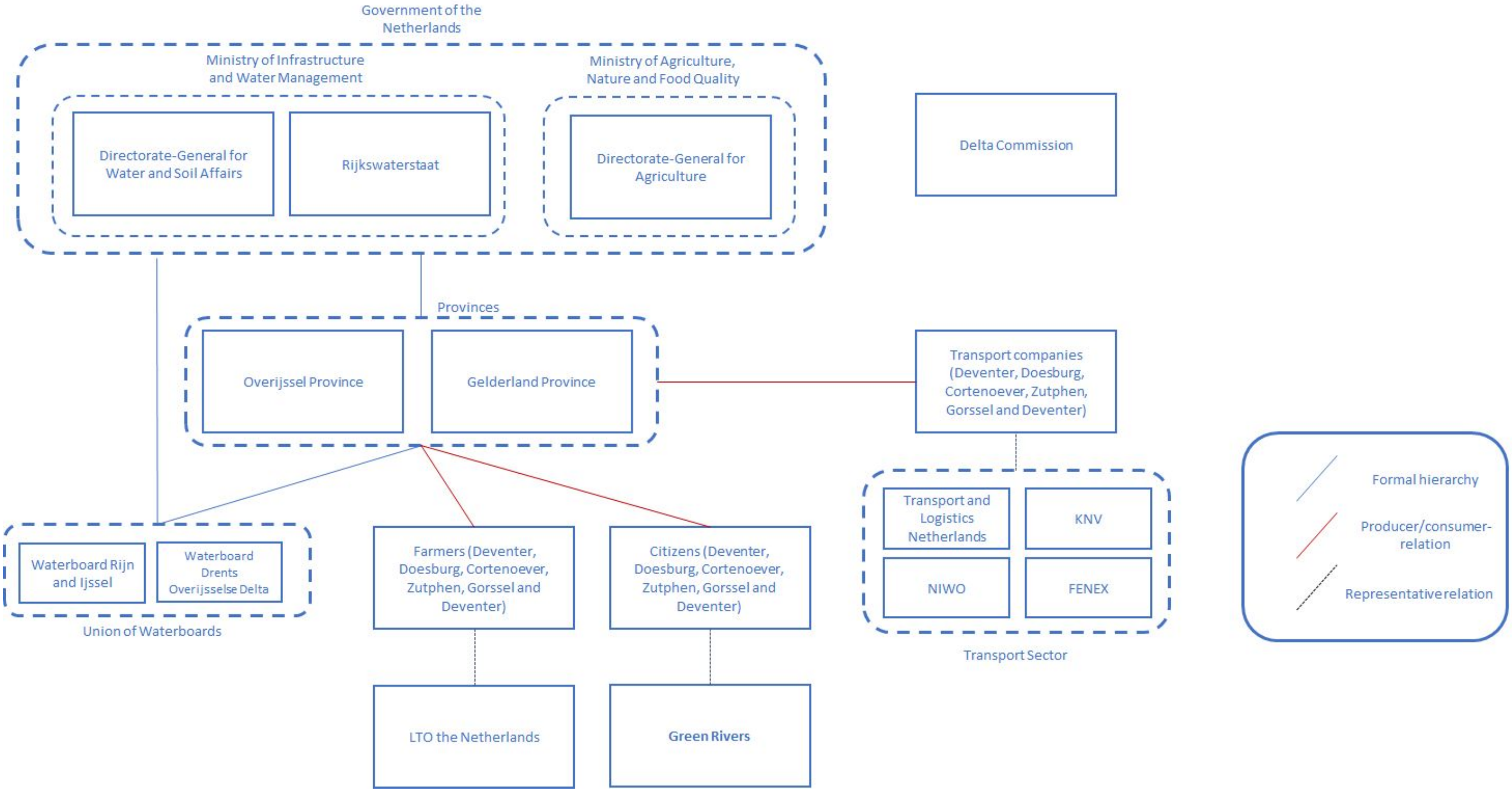

Figure 3. Relevant stakeholders for Room for the River across the IJssel river.

The IJssel area covers both the province of Overijssel and the province of Gelderland, where the potential locations for Room for the River are situated. The IJssel river meanders a lot and that both natural and urban areas are imbedded in the IJsseldal (Room for the River, 2017). The decision-making process can therefore be understood from various perspectives, for there are also economic, safety, and life quality concerns that stakeholders find to be of great importance. It is important to understand these interests and objectives as well.

1.3 Problem Formulation

The diversity of interests and objectives lead to different preferences for the policy alternatives. This report will form an advice for the environmental interest group "Green Rivers"[1], in order to deal with the diversity and uncertainty. For Green Rivers, it is crucial to contribute to the decision-making process by highlighting the importance of the environmental interests which are at stake. Making room for the IJssel river has positive effects on the environment. Research has shown that introducing flood plains with natural vegetation can increase the biodiversity of that area.
As biodiversity loss is currently increasing, which has high impacts on mankind (Cardinale et al, 2012; Diaz, Fargione, Chapin III & Tilman, 2006), creating room for the river can be valuable for slowing down this process. That is why Green Rivers should contribute to a composition of dealing with flood risks in which room for the river is highly present. Therefore, the problem is formulated as follows:

> *How can the usage of Room for the River be maximized in the IJssel river area, under deep uncertainty, given the various perspectives of the stakeholders involved in the decision-making process?*

In this problem formulation, '*maximized'* relates to the extent to which the proposed policy of Rijkswaterstaat incorporates the implementation of Room for the River. The more locations will have Room for the River implemented, the better this will be for the environment and biodiversity in the area. It is necessary to understand this policy alternative under '*deep uncertainty'* in this respect. 'Deep uncertainty' is linked to the various perspectives of the stakeholders. One refers to deep uncertainty in a situation when stakeholders or decision-makers do not agree on appropriate models to describe interactions, the expected future developments and the desirability of the outcomes, and the system of interest being studied (Maier, Guillaume, Van Delden, Riddell, Haasnoot & Kwakkel, 2016). In this case, every stakeholder will have a different evaluation of the impacts of the different policies along the IJssel river. Together with the uncertain future developments, such as the height of the increasing water discharge into the IJssel, these different evaluations show that the system at hand should be analysed under deep uncertainty.

1.4 Methodology

In order to research the problem formulation, it is important to have a better understanding of the interests and objectives of the stakeholders who are involved. This will be done through interviews with relevant stakeholders at the Rijkswaterstaat IJssel debates on June 7 and June 13 2019. Analyzing the flood protection along the IJssel river will be done using a model made by Alesso Ciullo (Ciullo, de Bruijn, Kwakkel & Klijn, 2019). The model is a case specific hydrological model, able to calculate the costs of failure over different aggregation levels given uncertainty in relevant factors. By taking the different preferences of stakeholders in the decision-making process into account, it is possible to use the model to

[1] https://sites.google.com/view/green-rivers/
https://github.com/WKSu/Model-based-decision-making/

gain a better understanding of the effectiveness of different policies from multiple perspectives.

1.5 Report Structure

Chapter 2 contains an overview of the involved actors and their interests. Chapter 3 operationalizes the problem formulation by translating the goals of the actors into the model that is being used in the analysis. Chapter 4 discusses and motivates the analytical methods being used. The results of the analyses are then discussed in chapter 5, followed by recommendations in chapter 6. Chapter 7 concludes with a reflection on how the analysis should be used and presented to have an impact on the decision-making process.

2. Multi-Actor Arena

This chapter explains the involvement of the different stakeholders in the IJssel river arena. The interviews with relevant stakeholders were conducted on official meeting dates for the IJssel river debates on June 7 and June 13 2019, during which stakeholders were asked to provide their concerns about the policy alternatives. Every paragraph provides an overview of the involvement for a specific stakeholder, with specific interests and goals.

2.1 Green Rivers

As an environmental interest group, Green Rivers is in favour of nature-based solutions, such as Room for the River. In the past century, the loss of animal species and plants in the Netherlands has been more than the average loss in Europe. Since Room for the River uses existing nature for flood protection, this policy would support the improvement of the biodiversity quality (Utrecht University, 2017). Therefore, Green Rivers supports the government mandate which takes the possibility of carrying out Room for the River into account: “nature is being given space to flourish along rivers, which also protects the surrounding area against flooding. A good example is the nature development project along the river IJssel (Government of the Netherlands, 2019a).

Dike heightening on the other hand is not preferred because it damages natural areas. This was the case with Grevelingen due to the Delta Works. Grevelingen is a freshwater area neighboring the Biesbosch. Not only was nature lost after a dam was constructed in Grevelingen, but the migration of different fish populations between Grevelingen and Biesbosch was also hampered because no fresh water was used in Grevelingen (Visscher, 2018).

Nature provides communities with ecosystem services, which can be cultural, provisional, or regulating (Figure 4). The Millennium Ecosystem Assessment reported a decline in 15 out of the 24 assessed ecosystem services on a global scale. In the Netherlands, the impacts of climate change have called for a greater demand for water storage and coastal protection, while the supply of water and soil fertility has declined (PBL, 2019). Since there are no specific policies for ecosystem services, Green Rivers therefore supports the inclusion of ecosystems in decision-making and incorporating quantitative measurements for the quality of ecosystems in Cost-Benefit Analysis (CBA).

Figure 4. An example of ecosystem services in the Netherlands (PBL, 2019)

2.2 Rijkswaterstaat

Rijkswaterstaat strives to improve the quality of life, access and mobility through effective water management for flood protection (Government of the Netherlands, 2019b). Rijkswaterstaat is an executive agency of the Ministry of Infrastructure and Water Management, which formulates a final policy recommendation for the projects to be carried out in the IJssel area. The existing flood risks in near the IJssel river call for solutions which are safe, beneficial for the quality of life in the region, and at the same time, do not weaken ecosystem services. The last pillar that should be present in the possible solutions is the mobility factor, which also interests the transport companies (paragraph 2.5).

2.3 Delta Committee

The Delta Commission was founded by the Dutch government to provide recommendations on how to protect both coastal regions and inland areas from floods on the long term (Government of the Netherlands, 2019c). The commission wishes to facilitate a solution which takes the concerns of all involved stakeholders into account and can dismiss the final policy recommendation of Rijkswaterstaat in case the interests of stakeholders are insufficiently taken into account.

2.4 Provinces

2.4.1 Province of Gelderland

The upstream province of Gelderland has important cities and rural areas around the IJssel and are the first province to suffer the consequences of a flood. As their land usage is found to be important, due to agricultural activities, for instance, the province prefers heightening their dikes to save space. However, if this were to happen, the flood risk gets moved towards the downstream province of Overijssel. Therefore, this province of Overijssel prefers the implementation of Room for the River to ensure safety for all areas around the IJssel (Province of Gelderland, 2019).

2.4.2 Province of Overijssel

The downstream communities in the province of Overijssel, would benefit from flood management which aims at reducing the water volumes flowing from Gelderland to Overijssel. However, the province is also concerned about the impacts of Room for the River for the agricultural activities, since it is feared that Room for the River will reduce the available land for farmers and with that, their source of income. (Province of Overijssel, 2019).

2.5 Transport Sector Representatives

The representatives of Transport and Logistics Netherlands, KNV, NIWO and Fenex represent the concerns of the transport companies that use the IJssel as a means of maritime transportation of goods across the Netherlands.

More than 30% of Dutch goods are transported on waterways in the Netherlands (Figure 5). De IJssel river has been classified as one of the main waterways for national and international transportation of goods (CBS, 2009). A main waterway allows for transportation of at least 5 million tons of goods, or 10.000 containers (CBS, 2019).

In 2018, extreme drought led to lower water levels forced maritime transport companies to carry less cargo (Waterboard Rijn and IJssel, 2018). Under these circumstances, it is possible for economic costs to rise up to 345 million euros (Ecorys, 2019). As some possible configurations of Room for the River imply a decrease in current water levels as well, it is feared that this will also negatively affect the revenues of the transport sector. Ships will be forced to limit their cargo capacity due to restrictions on how deep vessels can reach below the surface (Waterboard Rijn and IJssel, 2019). In order for their transportation to function properly, the representatives of the transport sector prefer dike heightening because it is expected that it will not lead to technical problems due to reduced water levels (Smienk, 2003).

Figure 5: the waterways for transport of goods in the Netherlands (CBS, 2009)

3. Operationalization

Analyzing the flood protection along the IJssel river will be done using a model made by Alesso Ciullo (Ciullo, de Bruijn, Kwakkel & Klijn, 2019). The model is a case specific hydrological model, able to calculate the costs of failure over different aggregation levels given uncertainty in relevant factors. This chapter discusses how the model is used for this report. For in-depth background information on how the model works, the article by Ciullo et al. (2019) is recommended.

As the IJssel simulation model is central in formulating advice for the Green Rivers to maximize the usage of Room for the River, it is important to translate their goals into properties of the model. In this chapter, each part of the model will be related to the goals of the Green Rivers, which will show which parts to focus on, when analyzing the simulations created by the model. Figure 6 shows an overview of how the model is set up, using the XLMR notation (Kwakkel, 2017; Lempert, Popper, Bankes, & RAND Pardee Center, 2003). The model translates policies (L) into outcomes, based on internal relations and the external uncertainties.

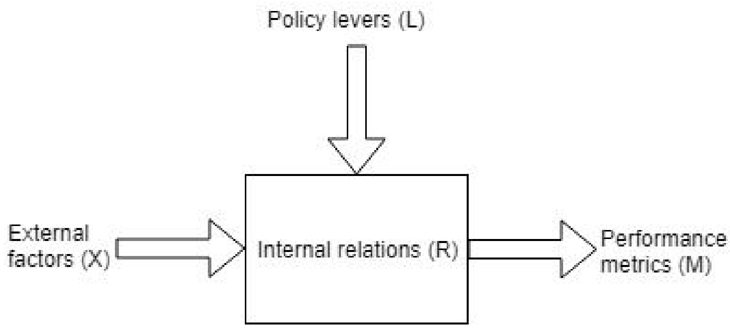

Figure 6. Blueprint of the model and its components.

3.1 Operationalizing the problem formulation

In order to perform useful analyses with the model by Alesso Ciullo, it is important to start with translating the initial problem formulation into the possibilities of the model:
How can the usage of Room for the River be maximized in the IJssel river area, under deep uncertainty, given the various perspectives of the stakeholders involved in the decision-making process?
In relation to the model, Room for the River alternative can be implemented in multiple locations, at multiple timesteps, as a means to lower the effects of possible floods. Keeping the outcomes and uncertainties of the model in mind, the problem formulation can be translated into the following model problem statement: *How to minimize the costs, deaths, and damages of floods by applying flood mitigation and protection measures, while promoting biodiversity and nature areas, under deep uncertainty?*
Each part of this model problem statement will be elaborated on in the remaining paragraphs of this chapter. Finding an answer to the question will be a technical base for creating advice for Green Rivers.

3.2 Aggregation level

There are multiple locations where dike heightening and/or Room for the River must be considered. These are: Doesburg, Cortenoever, Zutphen, Gorssel, and Deventer, which are represented in the model as A.1 - A.5. Due to the different properties of each of these locations, there could be a significant difference in the profitability of projects in the different locations. As Green Rivers want to maximize the usage of the Room for the River alternative, it is important to gain knowledge of the relative profitability of this alternative for each of the locations. Although maximizing Room for the River usage is not dependent on the location, it can be important to get other actors on board, which can be done by showing the optimal locations for implementing Room for the River. Especially the provinces are important when it comes to location, as their land space would be used for creating Room for the River. To make sure that none of the locations will carry all the weight, the model will be disaggregated over location.

Next to the geographical dimension of the possible projects, time also plays a role. Green Rivers are in favour of using Room for the River as a permanent solution, which should thus be implemented as soon as possible as to cause lock-in. 3 separate moments for decision -making are considered, which means every 66 years a decision to implement projects can be made, as the model runs for 200 years. Considering the model, both of the dimensions should be taken into account in order to get a clear and useful view on the situation.

3.3 Uncertainties

Five different uncertainties are implemented in the model. Table 1 gives an overview of these uncertainties and their attributes, which can differ per location.

The uncertainties in the model can point out worst case scenarios and the value of the green alternative of creating Room for the River. The discharge of the river, together with the severity of a possible flood, show how necessary interventions are, which is why they need to be taken into account.

Table 1. Overview of uncertainties in the IJssel river model.

Factor	Description	Range	Units
Flood wave shape	Describes the discharge at the most upstream location	0-140	
Dike failure probability (per location)	The higher this value the lower the chance that the dike fails	0-1	
Final breach width (per location)	Indicator of the total volume of water that enters through a dike breach	30-350	m
Breach width model	Growth rate of the dike breach width over time	1, 1.5, 10	1/day
Discount rate (per timestep)	Interest rate used to calculate the net present value	1.5, 2.5 , 3.5, 4.5	

3.4 Levers

The possible ways to intervene in the system are as follows: an intervention takes place at a specific location, at a specific time step. An intervention can be either Room for the River, heightening the dikes, or implementing a warning system. From the perspective of Green Rivers, the levers should focus on the usage of Room for the River, which should be maximized. The way in which this usage is measured, will be explained in the following section. An overview of the described levers can be found in Table 2.

Table 2. Policy levers in the model.

Lever	Description	Range	Unit
Room for the River (per location and timestep)	RfR projects widen the river bed thus lowering the water levels associated to a given water volume. There are five RfR projects which can be either implemented or not (1 or 0). Each project corresponds to a profile of water level reductions across locations.	0-1	
Dike heightening (per location and timestep)	Amount of dike raising. The higher the dike, the higher the hydraulic loads it can stand.	0-10	dm
Early warning	Early warning systems anticipate a threat and help limit damage and avoid casualties. The earlier the alert, the more effective the response, but also the more uncertain it is that the event will actually happen. False alerts can be costly and undermine people's trust in the authority. Waiting too long is also problematic as the efficacy of late alerts is poor. In the model you can choose how much time in advance to give the alert.	0-4	Days

3.5 Outcomes

The outcomes that are included in the model can be categorized into two groups. On the one hand, there are the costs of the implementation of protecting and mitigating measures, which exist as the costs for Room for the River projects, dike heightening projects, and warning system projects. The other group of outcomes represent the damage in case of a flood, which exists as the number of deaths and the damage done to property. Table 3 shows an overview of the existing outcomes and their unit.

Table 3. Model outcomes and their unit.

Outcome	Description	Unit
Expected annual damage (per location and timestep)	Expected annual value of flood damage over the planning period. Clearly, for each location, the lower this value, the better.	€
Expected number of casualties (per location and timestep)	Same as above but related to amount of casualties and not economic damage.	
Dike investment costs (per location and timestep)	Investment costs of raising dikes.	€
Evacuation costs (per timestep)	Function of the number of people evacuated and the number of days they need to be out from home. The estimation is based on the 1995 evacuation in the Netherlands.	€
Room for the River costs (per timestep)	Investment costs of the implemented Room for the River project.	€

3.6 Constraints

With regards to the environment, many important criteria that should be taken into account are missing from the model. However, considering the possibilities of the model, the outcomes can be shaped in a way that is valuable for Green Rivers. As Room for the River projects are preferred above others, the investment in alternative solutions can be seen as undesirable. That is why, a constraint could be placed on the costs of dike heightening investment. This will lead to dike heightening becoming a less desirable solution than when only the costs between alternatives are taken into account. The more this alternative is used, the higher the “punishment” would be. This punishment should be higher than a linear fashion, as the way the model is set up, the cost of dike heightening is already minimalized, meaning a linear constraint does not have any effect. Implementing an exponential punishment would have an effect, but a lack of knowledge on the height of this punishment takes away the opportunity to implement it. If further research could indicate this height, it could be implemented into the model.

To add the missing environmental criteria to the model, without changing the structure of the model, the costs of investing in Room for the River could be lowered. This lowering of the cost could be translated to a subsidy in the real world, or to the positive side effect that Room for the River has for the environment. Although research pointed out the benefits for other rivers (Bos & Ruijs, 2019; Moosa & Ramiah, 2014), a lack of knowledge on the height of these benefits in the IJssel takes away the opportunity to implement this change in a meaningful way. Additional research into this height could be a base for implementing this change in costs into the model.

Another possible way to incorporate the desirability of Room for the River into the model is to put a soft constraint on the costs for implementing Room for the River. This would transpose the costs into a way in which the costs are interpreted as 0 until they reach a certain level, from which costs do start to increase as a punishment in the constraint function. The height of the tipping point from which costs start to occur should also differ per time step in which the project is implemented. Because animals need time to acclimatize, the environmental benefits of implementing Room for the River are higher when the projects happens in an early stage. Translated into the model, this means that the minimal investment constraint in Room for the River will be higher in earlier timesteps. The tipping points will be *426.24, 284.16* and *142.08* euros in timesteps 1, 2 and 3 respectively. These numbers are retrieved from the model and represent the costs of implementing 3, 2 or 1 average Room for the River projects. In other words, implementing 3 projects in timestep 1 will cost as much as implementing 2, 1 or 0. Because the model will also minimize property damage and the expected number of deaths, the model will pick implementing more projects over implementing no projects, as the costs are the same, but the damages are less.

By changing the outcomes in the described ways, in optimization, the model will converge to solutions that are closer to the desires of Green Rivers and represent the environmental criteria better than before. Although the height of the tipping points is again hard to base on real world data, the aforementioned trivial numbers have been chosen. This lowers the validity of the model, but increases the usefulness, which is why it is seen as justified.
Next to the costs of the implementation of either of the three possible solutions, also damages and casualties are important. Though these criteria are not primarily present on the agenda of Green Rivers, they should be taken into account, because the other actors in the arena have to consider them. Therefore, solutions should be found that do not only make use of Room for the River as much as possible, but also vow for low damages, in order to reach consensus on the preferred solution.

4. Methodology

The IJssel river model discussed in chapter 3 is key to the analysis performed, but it does not yet cover further analysis methods used. Analysis on the IJssel river model was performed using the Exploratory Modeling Workbench in Python (Kwakkel, 2017). The workbench is a Python library that provides access to various exploratory modeling techniques in Python. This chapter will discuss what analysis methods in the workbench were used on the model, why they were used, and how. The paragraphs are directly based on the way the python notebooks are set up. Each paragraph belongs to one of the notebooks, which will be mentioned at the end of each paragraph.

4.1 Modelling Cycle

To create a well funded advice for Green Rivers, it is necessary to search the solution space of the IJssel river system thoroughly and to find policies that will work independent of the scenario that takes place. The chosen way of finding interesting policies is by looking at the system in a pessimistic way. Abraham Wald (1945) introduced this way of deciding on the best outcome, on which has been elaborated, in “A Theory of Justice” by Rawls (1972). The main idea is to minimize the effects in the worst case that could happen. As the impact of a lack of intervention in the IJssel river could result in relatively high damages and human lives, it is unacceptable to underperform. Thus a policy should be able to deal with any scenario imaginable and in particular the worst case scenarios. Assuming that the policy will also be acceptable in average or good scenarios, this maximin approach is the logical choice. Therefore, the performed methods focus on finding policies that work best in the worst case scenario that could take place. Then, to make sure that these policies are not too scenario dependent, the policies are tested on the full range of scenarios, to see whether their impact is also acceptable in less extreme scenarios.

Translating this approach to the available methods, the first step of the analysis will be to find the worst case scenarios. The first graph of Figure 7 shows how the usage of the Patient Rule Induction Method (PRIM) and Classification And Regression Trees (CART) can pinpoint scenarios that are assumed to be “worst case”. In paragraph 4.2 this step will be elaborated on.

To put the problem into perspective, the possible futures without any intervention are compared to the several random intervention techniques, which are combinations of levers explained in paragraph 3.4. This will show if doing nothing is acceptable as an option.

After selecting the subset of scenarios that holds the worst cases, several policies will be searched for, which can cover for the impact of effects in the worst case scenarios (the second graph of Figure 7). Making use of Multi-Objective Robust Optimization (MORO), policies will be located that are robust and optimal in dealing with the worst case impact. MORO searches through the uncertainty space which is defined, it looks at the effect of the policies across a larger space to make sure the policies are not sensitive to small changes in the scenarios. In this, the uncertainty space MORO can look at is derived from the worst scenarios when there are no policies implemented. As the case of the IJssel river has high uncertainty and the effects of floods are unacceptable, it is necessary to look not only for good solutions, but also robust ones. If no policies have been found that have converged to an optimum, MORO will be ran again, making use of a longer period of searching. MORO will be explained further in paragraph 4.3.

The policies that have been highlighted by MORO as robust and optimal in the worst case scenarios will be evaluated over the whole uncertainty space as well, to make sure that they are not too specifically focused on the worst case scenarios. Although the found policies will probably not be optimal in each and every existing scenario, it is important to look at their behaviour across all scenarios (shown in the third graph of Figure 7). It is then up to Green Rivers and the other actors to decide to what extent the policies are actually desirable. A final step in the analysis is to remove policies that do not make much sense or are relatively hard to perform, such as applying both Room for the River and the highest form of dike heightening at the same location. Paragraph 4.4 shows further how the policies will be analyzed.

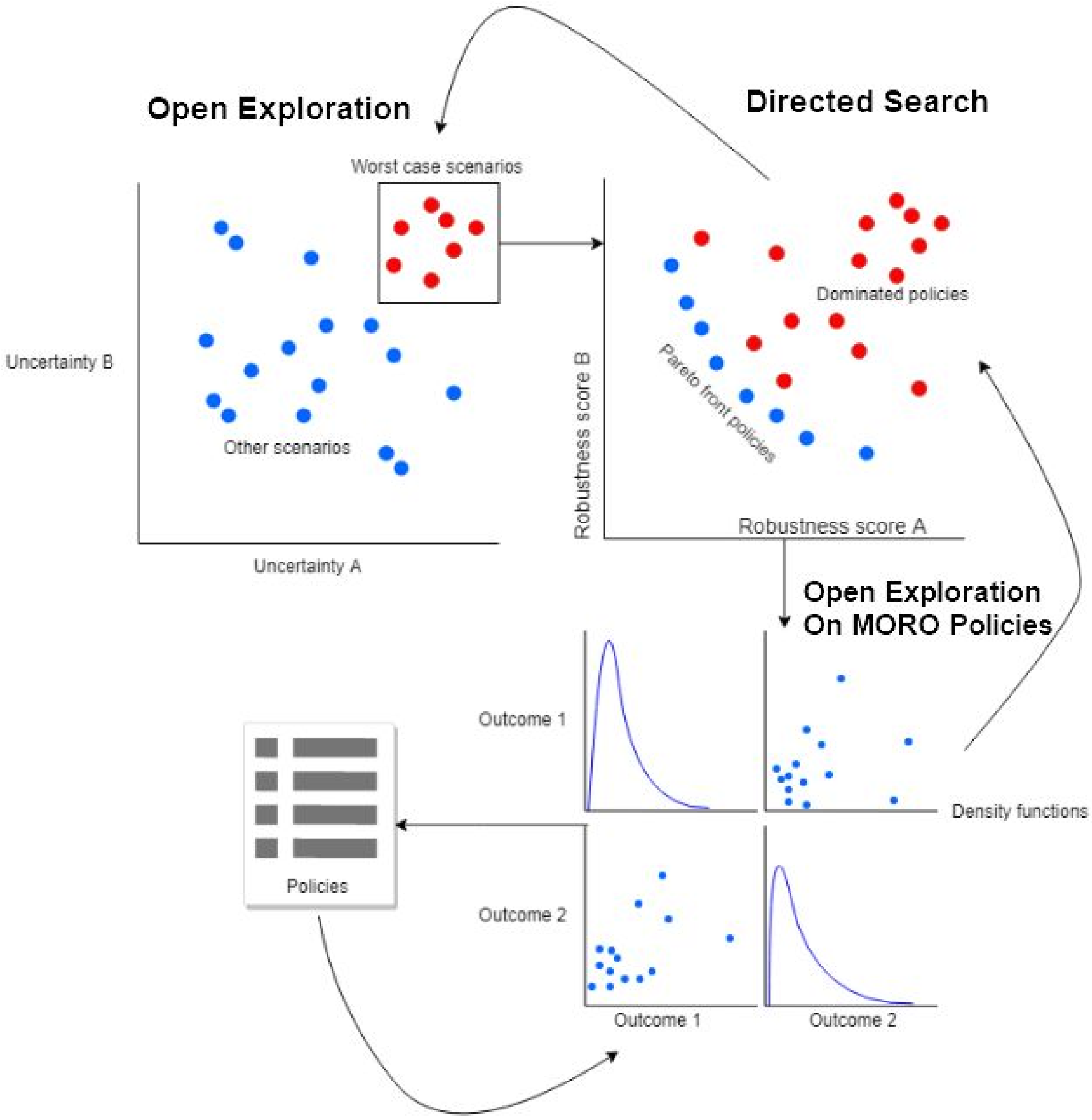

Figure 7: Roadmap of the performed methods and the relation between them.

4.2 Open Exploration Base Case

As a start, random policies and scenarios are sampled using Latin Hypercube sampling to get an overview of the uncertainty space. A 1000 runs will be performed, without the implementation of any policy. Then within this space, for both the total damage done and the number of deaths, rules will be found that can separate the worst scenarios from the others. This will have a shape of cutting the most impactful uncertainty ranges. This cutting process will take place on base case scenarios, as this is assumed to be the worst outcome. In 4.3 this assumption will be justified by comparing the base case to situations in which policies are implemented.

For deaths the worst 15% of scenarios will be found and for damage the worst 10%. The determination of these exact percentages has been done through iteration. The percentages chosen can be found with clear rules for the partitioning of uncertainties. To achieve this set

of partitioning rules, first the partitioning process will be performed by the Patient Rule Induction Method (PRIM), which will show plots of the partitioning rules that it comes up with. These can be interpreted to gain insight on what the important uncertainties are.
CART will then give specific rules for the partitioning of the most impactful uncertainty ranges (Breiman, 2017), which can be compared to the outcomes of PRIM to see if they make sense. These smaller ranges will be input for the optimization step which will be elaborated on in paragraph 4.4. Everything described in this paragraph can be found in notebook: “1-Open-Exploration-Base-Case.ipynb”.

4.3 Open Exploration with Policies

An in-between-step before performing the robust optimization, is to check whether having no intervention could be beneficial as a policy. To check this, 400 scenarios will be performed with 75 different policies implemented. Boxplots of the outcomes of both the base case from paragraph 4.2 and these scenarios will be compared in order to get a view of the necessity of intervention. The data of these policy based scenarios will further be used in notebook “3-Directed-Search-MORO.ipynb” to find the hypervolume ranges for MORO. Everything described in this paragraph can be found in notebook:
“2-Open-Exploration-400scenarios-and-75policies.ipynb”

4.4 Directed Search with Multi-Objective Robust Optimization

The challenge in the IJssel river case is that optimization has to be performed over multiple conflicting objectives. When looking at multi-objective problems, the solutions on the Pareto-front are seen as a collection of potential viable solutions (Coello, Lamont & van Veldhuizen, 2007). However, this is still likely to be a large set of solutions that aren’t all attractive in practise, as some objectives could be sensitive to changes in variables. If this sensitivity is too high, then the solution is likely to be undesirable. To introduce robustness in multi-objective problems, solutions on the Pareto-front must also be insensitive to small changes in input variables (Deb & Gupta, 2006), in other words, solutions should be able to deal with uncertainty (Hamarat, Kwakkel, Pruyt, & Loonen, 2014).

Table 4. Calculating the robustness metric

Mean	**Interquartile range**	**Interquartile range + (0.05 * mean)**	**Robustness metric: mean * (interquartile range + 0.05 * mean)**
10	10	10.5	105
20	1	2	40

To find a robust solution multi-objective robust optimization (MORO) will be performed. In this analysis, each of the outcomes explained in paragraph 3.5 will be minimized. After some iterations it has been found that the algorithm needs many scenarios and nfe (number of functions evaluated) in order to converge to optimal solutions. Therefore 50 scenarios will be used and 20000 nfe’s. As the model has approximately 16.000 different scenarios, but a part of them were sliced off during the CART algorithm, 50 scenarios come down to 5% of the possible scenarios, which is considered to be acceptable. To cope with the extreme computational cost that comes with such a high amount of runs in MORO, an Amazon EC2 m5.24xlarge server will be used in order to keep runtime acceptable (96 CPU cores, 384gb of RAM).

A key aspect of this approach is defining the robustness metric that will be used in the optimization process. This step has a big impact on the whole analysis as the chosen robustness metric is likely to affect the outcomes (McPhail et al., 2018). The robustness metric in this analysis is defined as the mean of each of the outcomes multiplied with the interquartile range. This does not only cover the height of each outcome, but also makes sure that the policies are robust in the sense that they will not differ largely if a small input change takes place. However, this way of calculating does leave room for solutions that are not desirable mean-wise, but do have a robust character. This is why, in calculating the robustness score, a fraction of the mean is also added to the interquartile range. In this analysis, the fraction will be 5% of the mean. This should ensure that no bad robust solutions are found in the optimization process. It also solves the problem of the possibility that the interquartile range can be close to zero for some variables. By adding a fraction of the mean, it is impossible that the robustness score also reaches towards zero, due to the low interquartile range. Table 4 shows the robustness metric calculation process with 2 examples to clarify what is happening within MORO.

Another specification of MORO is the set of constraints that were introduced in paragraph 3.6. To make clear how the constraint is actually used, the following pseudocode shows which steps are taken in the code in notebook: “3-Directed-Search-MORO.ipynb”:
If RfR Total Costs in timestep 0 are below €426.24 million, interpret them as 0, otherwise, subtract €426.24 million from the costs.
For RfR Total Costs in timesteps 1 and 2 the calculation happen in a similar manner, except for the tipping point being 284.16 and 142.08 instead of 426.24.

Convergence metrics used to test for algorithm convergence are the hypervolume indicator and epsilon convergence. For background information on these metrics readers are referred to Reed, Hadka, Herman, Kasprzyk & Kollat (2013) and Kasprzyk, Reed, Characklis & Kirsch (2012). The hypervolume range can be found using the data that is the result of performing the experiments explained in paragraph 4.3. The epsilon values will be found by performing a smaller MORO algorithm. The robustness function above was used to find the interquartile ranges, which will be used as the epsilon values (Kasprzyk et al., 2012). A final step in the MORO process, is to show trade-off plots to see if certain outcomes can only have a desirable value at the cost of another outcome. Everything described in this chapter can be found in notebook: “3-Directed-Search-MORO.ipynb”.

4.5 Open Exploration of MORO based policies

To further examine the policies that MORO has outputted to be optimal in the worst case scenarios, each of the policies will also be examined in the whole scenario space. This can further position the policies in terms of their vulnerability and profitability (Bryant & Lempert, 2010). It is likely that the policies examined here are not optimal for all of the scenario space, but as has been stated before, the focus in finding solutions is on minimizing the costs in the worst case. However, the found solutions should also be acceptable in the whole solution space, next to performing optimally in the worst cases. That is why it is important to show their performance across the whole space of scenarios.

If the found policies still underperform on any of the outcomes, the whole process can be carried out again. First feature scoring extra trees ("4-Open-Exploration-MORO-Policies.ipynb") will show which uncertainties cause the specific outcome to be hurt in implementing the found policies. This will again show the worst case scenarios for that particular outcome, which can be input for another iteration of MORO, to find even better, more robust policies. Due to a lack of computational power and time, in this analysis the iterative process will stop right before performing MORO again.

A last step in the analysis will be to remove found policies that are not feasible. Also, the policies that make use of Room for the River in at least one location will be highlighted as these policies are most preferable for Green Rivers. Everything described in this chapter can be found in notebook: "4-Open-Exploration-MORO-Policies.ipynb".

5. Results

This chapter presents the results found from the methodology discussed in chapter 4. The results are generally presented using tags. Table 5 gives an overview of the tags used when presenting the results.

Table 5. Tag Explanation for locations

Location	Tag
Doesburg	A.1
Cortenoever	A.2
Zutphen	A.3
Gorssel	A.4
Deventer	A.5

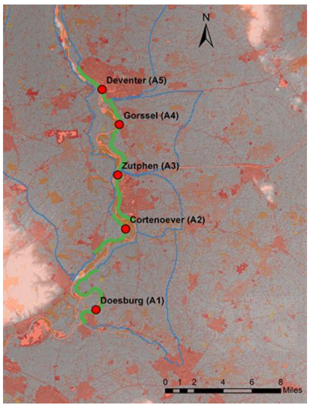

Figure 8. The different important locations along the IJssel (Ciullo, 2019).

5.1 Open Exploration Base Case

Open exploration was performed on the base case using 1000 scenarios. This has shown that when it comes to costs, location A.1 suffers the most damage on average by far, followed by A.3 (Figure 8). Histograms in Figure 9 also show the distribution in the base case, the right-end tail of the histogram in A.1 deaths is also very high. A.3 as a location suffers the highest impact of damages / deaths in the base.

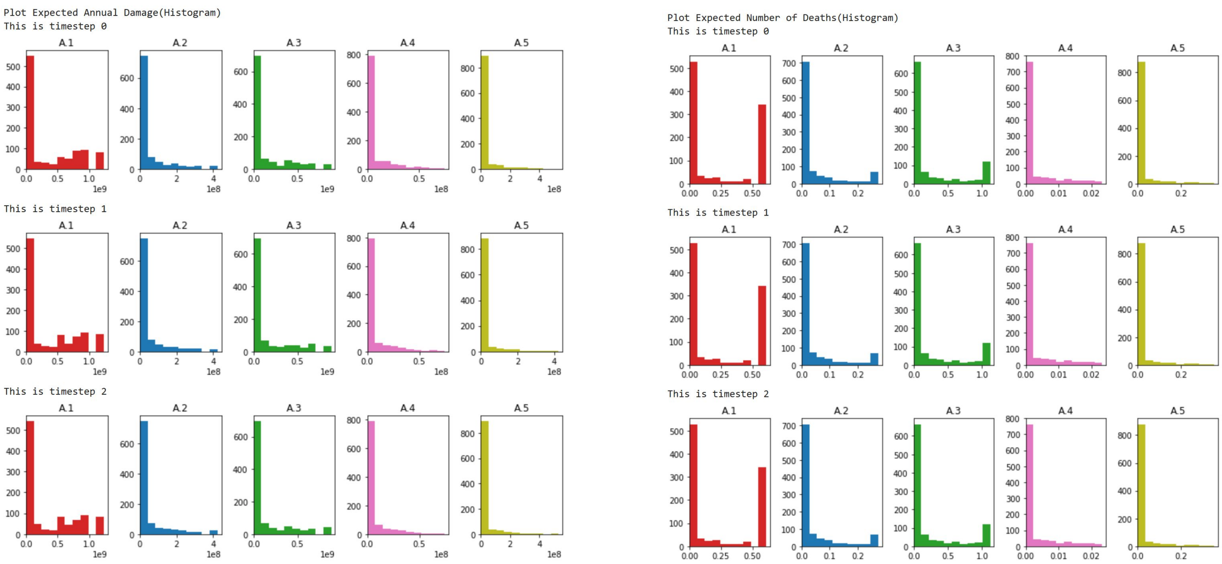

Figure 9. Histograms of annual damage and number of deaths per location per timestep.

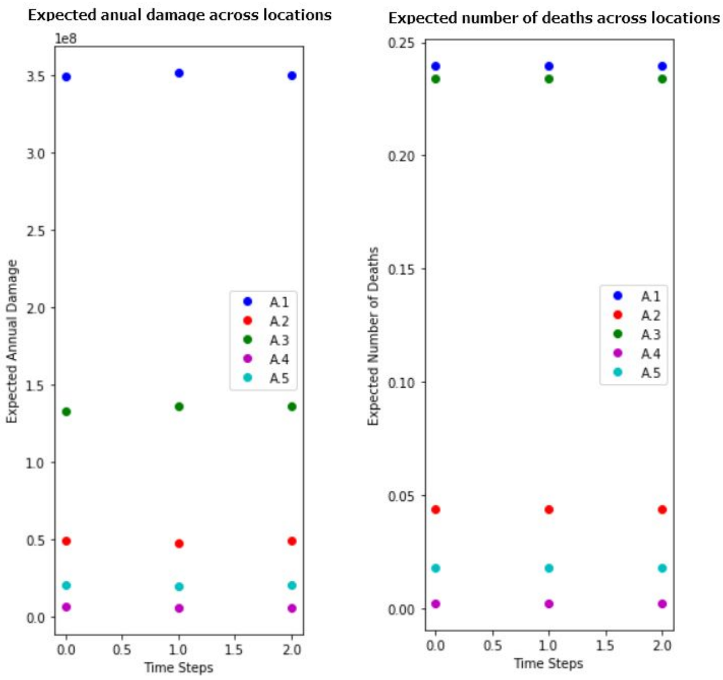

Figure 10. Mean of the costs and number of deaths in the base case per location and time step (1000 scenarios)

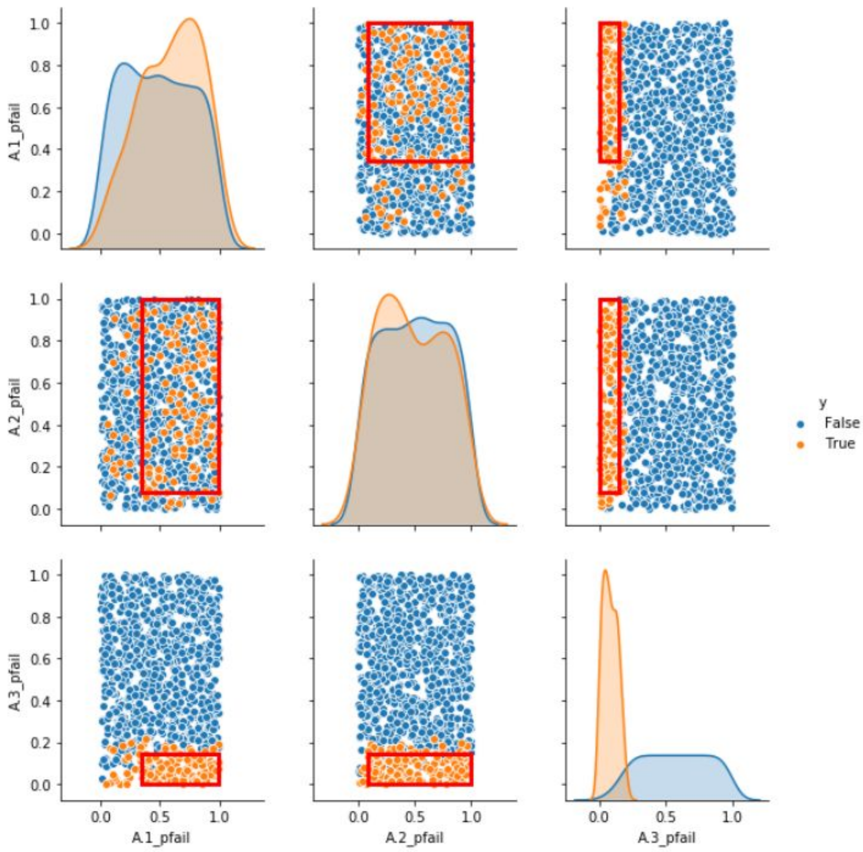

Figure 11. Patient rule induction method showing the impact of the pfail uncertainties

Figure 10 shows three of the uncertainties and how much the worst case scenarios are impacted by these uncertainties. The plot indicates that for both A.1 pfail and A.3 pfail, a low value has a high impact on the desirability of a scenario.

The trees in Figure 11 strengthen this finding further and show that both uncertainties have a high impact on the desirability of a scenario. Based on this, the range of uncertainties presented in 3.3 were narrowed down to a smaller set. These changes can be found in Table 6. These adjusted ranges cover the 15% worst case scenarios for the number of deaths and the 10% worst case scenarios for total annual damage. This means that if the probability of the protection measures working is lower than 0.367 in location A.1 and the same probability is lower than 0.226 in location A.3, the worst case scenarios take place. The locations in which the uncertainties are most important are no surprise. As Figure 9 showed, the most damage takes place in these locations, which means a failure of protection measures has the greatest. impact there.

The pairplots in the notebooks show the relationships of the values, they are not included in the report due to the loss of interactivity. Interesting to notice, is that pfail and deaths / damages have an interesting relationship. High damages and deaths are saturated around the low pfail ranges of locations.

Table 6. Overview of uncertainties in the IJssel river model.

Factor	Description	Full Range	New Range
pfail Dike failure probability (per location)	The higher this value the lower the chance that the dike fails	0-1	A.1pfail: 0 - 0.367 A.3 pfail: 0 - 0.226

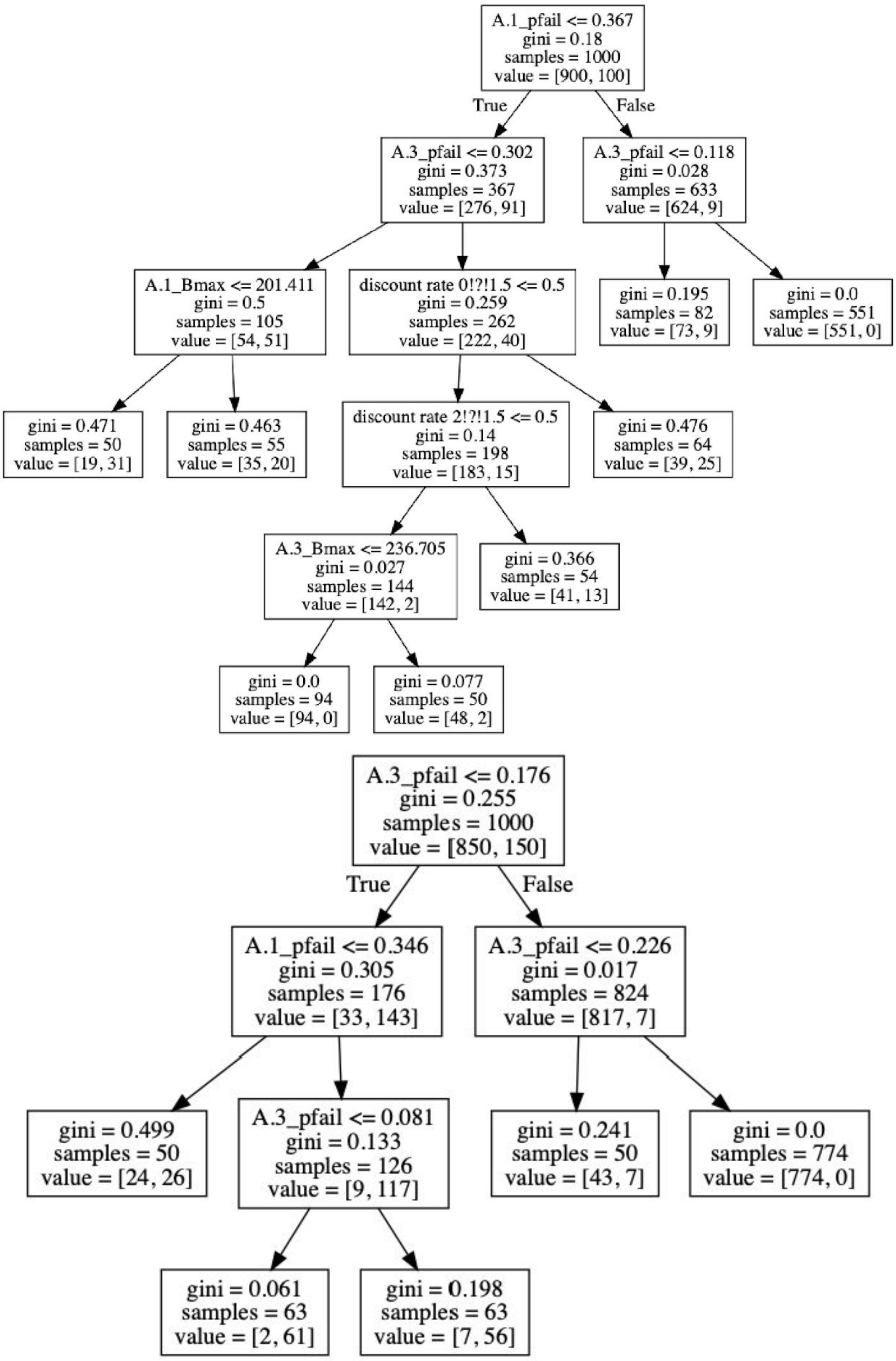

Figure 12 CART produced trees on damage (top) and number of deaths (bottom)

5.2 Open Exploration with Policies

After looking at the base case, the 75 different random policies were run in 400 scenarios using latin hypercube sampling. The results will be used to compare the scenarios that have policy implementation with the base case. Figure 12 shows a significant decrease in both the expected annual damage and the expected number of deaths compared to the base case. The damage costs went down from millions of euros to hundreds of thousands and the expected number of deaths decreased from 0.25 to 0.0015. This shows that doing nothing can be seen as (one of) the worst outcome that could take place.

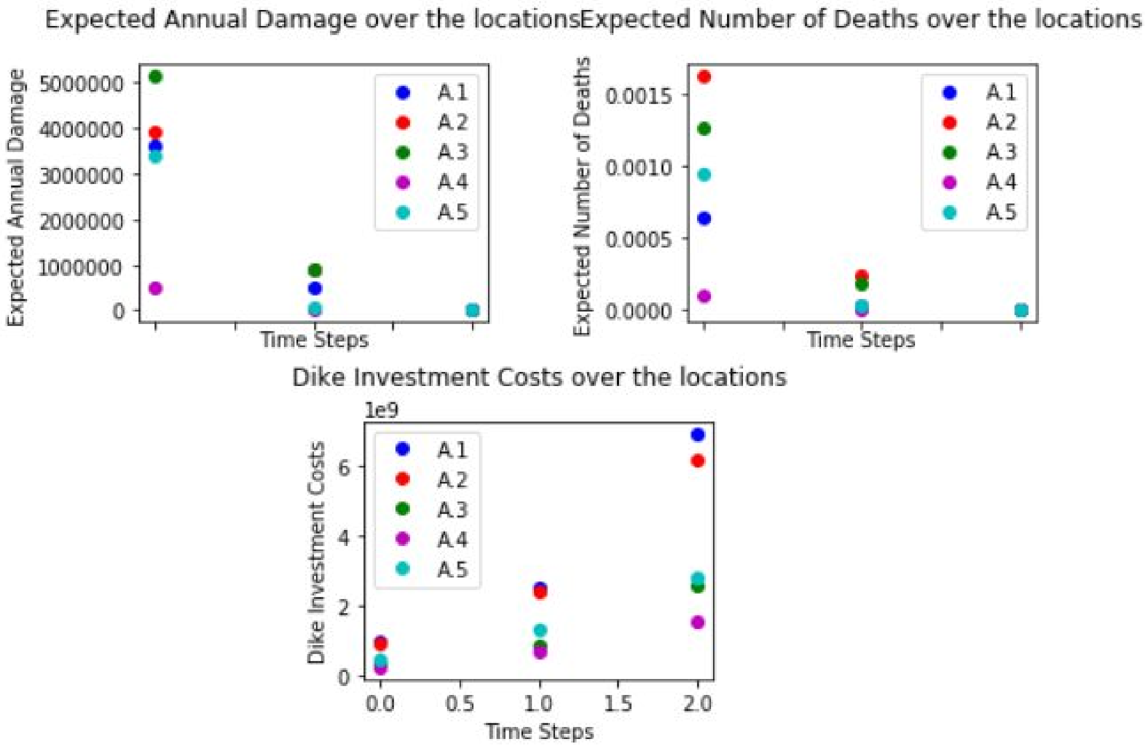

Figure 13. Mean of the outcomes in the policy implemented scenarios per location and time step (400 scenarios)

Looking at the aggregated outcomes in the boxplots in Figure 13 and 14, the difference between the base case and the scenarios in which a policy was implemented can be seen even clearer. Aggregated over both timesteps and locations, the number of deaths decreases from an average of 2 to an average of no higher than 0.05, differing per policy. The total damage of all timesteps and locations decreases from between 1 and 2 billion to approximately 1 million. Visual inspection shows a difference between the base case and the implementation of an average policy. However, a difference in negative sense can be found with regard to the investment costs. In the base case no policy takes place, so also no investment costs are made. Green Rivers would not be responsible for the payment of the investments, but it is important to keep in mind that the costs can go up quickly, which can matter in the decision making arena.

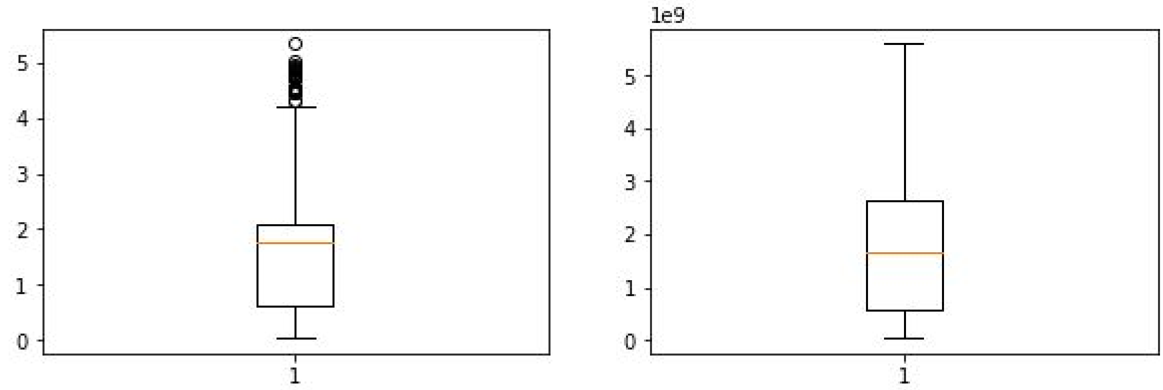

Figure 14. Boxplot of the base case for the number of deaths (left) and the total expected damage (right)

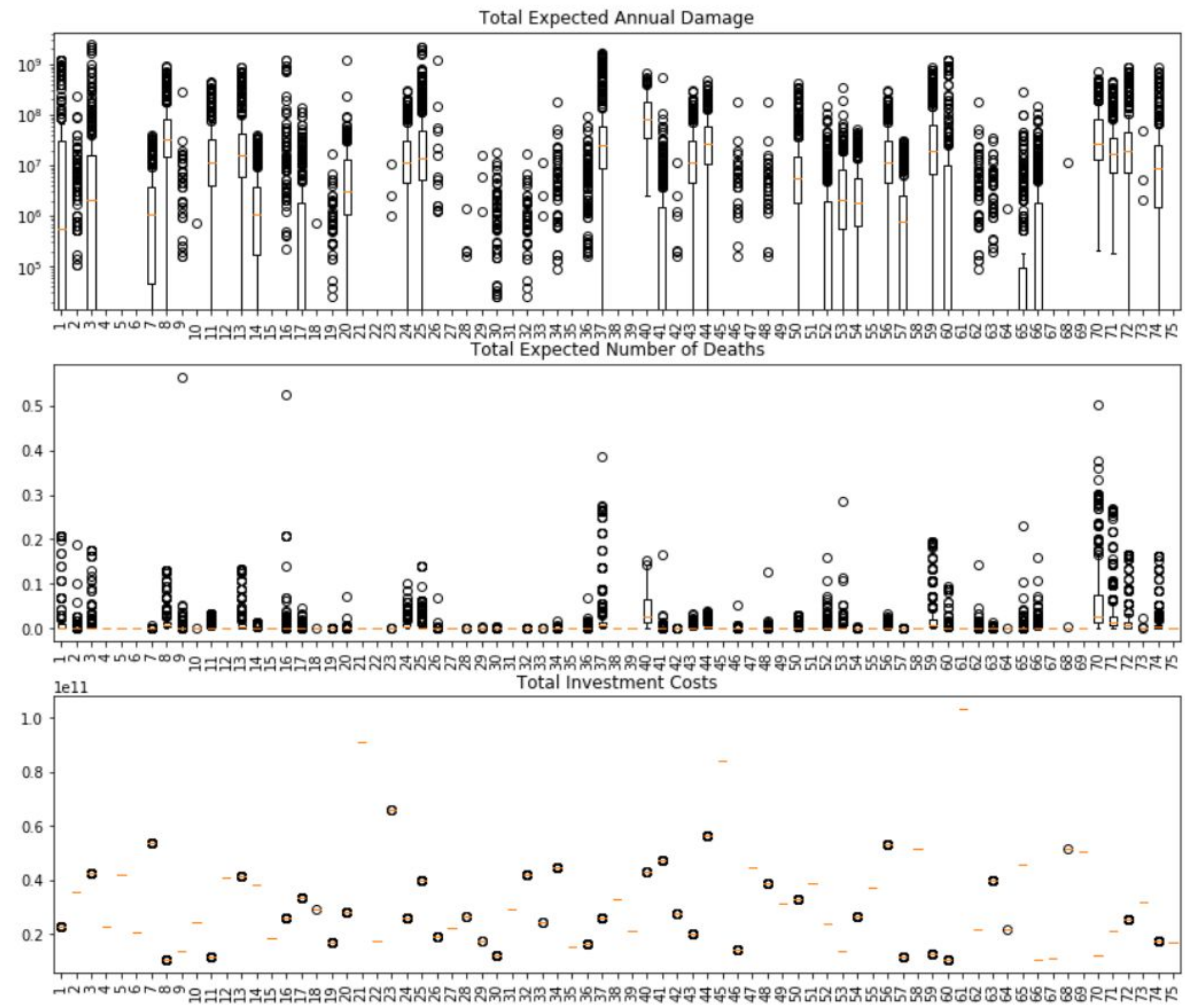

Figure 15. Boxplot of the scenarios with policy for the number of deaths (bottom) and the total expected damage (top)

5.3 Directed Search with Multi-Objective Robust Optimization

Using the values for the hypervolume and epsilon in tables 7 and 8, MORO was performed over the 50 scenarios and 20000 nfe's. Figure 17 shows that our epsilon values do seem to converge around 12,000 nfes. Unfortunately, the hypervolume indicator remains at 0. Two factors probably contribute to this:

1. The maximum value we set for the hypervolume may be so large that the hypervolume is so small relative to the total space that it is rounded to 0.00.
2. The maximum value is not large enough to capture the optimization outcome robustness scores.

Outside of these notebooks, smaller sample runs were tested with different expected ranges for the hypervolume. By varying hyp_ranges_max between 10e20 to 10e23, the value was defined between 0 and 1 (using some 'dirty hacks' to use the policies from the above run as the initial population for further optimization). Any higher values would yield 1 immediately. Thus, it can not be claimed that the hypervolume indicator has shown convergence for the problem.

This is not to say there is no confidence in the results. While two indicators could have been useful to understand the optimization, it is expected that the hypervolume will require further debugging.

Table 7. Overview of epsilon values per outcome.

Outcome	Epsilon value
Total Expected Annual Damage	3.287533e+15
Total Dike Investment Costs	3.660080e+18
Total Expected Number of Deaths	5.482093e+05
Total RfR Total Costs	1.096303e+17
Total Expected Evacuation Costs	4.118847e+10

Table 8. Overview of minimum and maximum hypervolume values per outcome.

Outcome	Hypervolume minimum	Hypervolume maximum
Total Expected Annual Damage	0.000000e+00	3.897572e+16
Total Dike Investment Costs	1.096392e+18	8.371133e+19
Total Expected Number of Deaths	0.000000e+00	1.127772e+07
Total RfR Total Costs	2.113227e+16	9.080500e+17
Total Expected Evacuation Costs	0.000000e+00	2.421692e+12

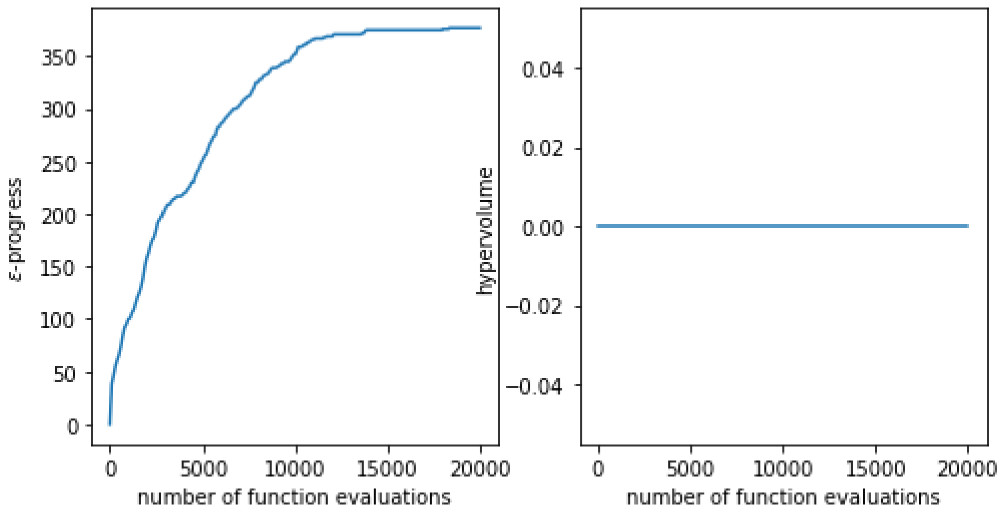

Figure 17. The visualization of the epsilon convergence.

5.4 Open Exploration of MORO based policies

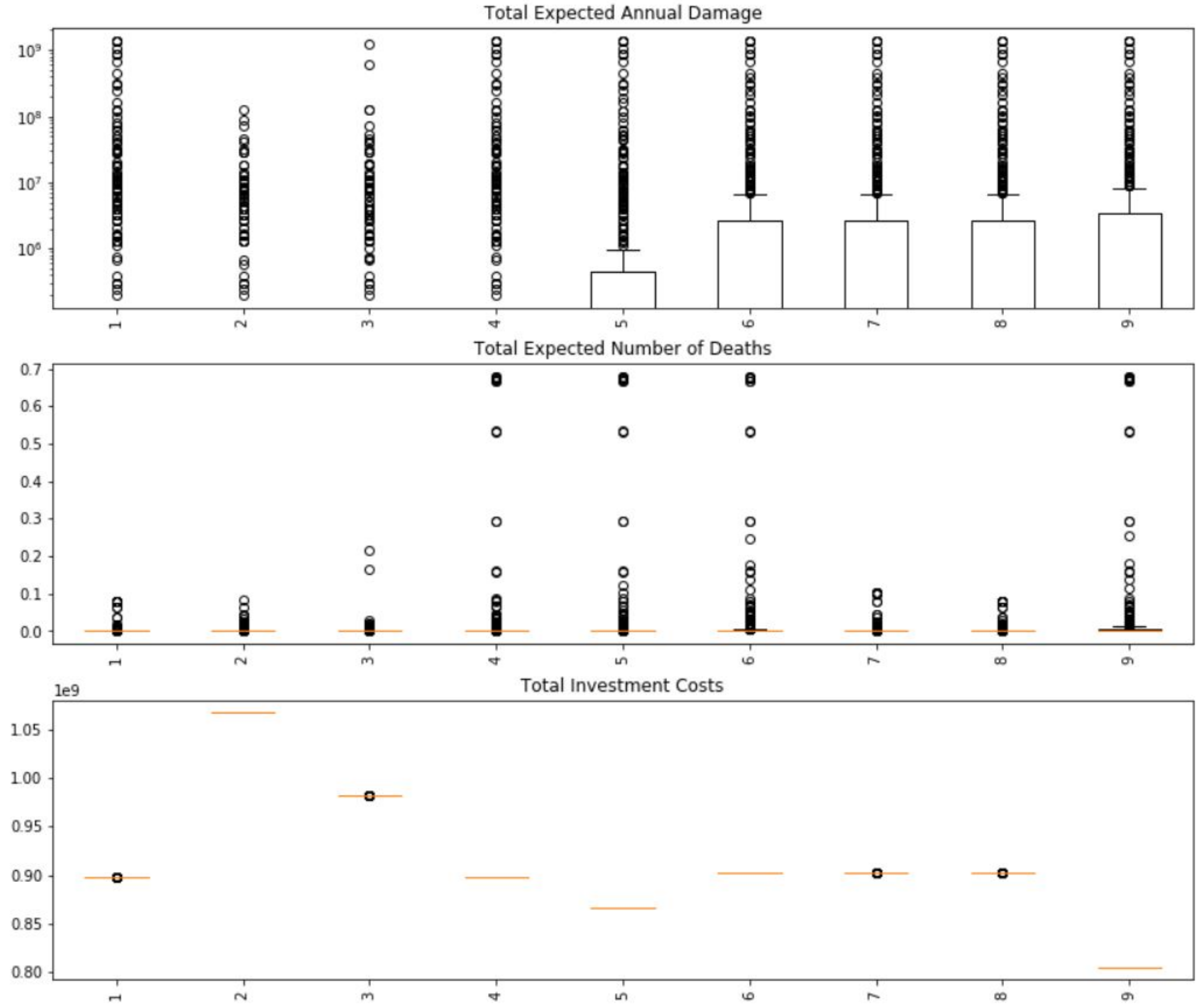

Figure 18. Boxplots of the optimal policies in worst case scenarios per outcome.

This paragraph discusses the policies that MORO has pointed out to be optimal in the worst case scenarios. Compared to the open exploration of the 75 policies in paragraph 5.2, the mean and the interquartile range in Figure 18 perform better than most policies in damages. The outliers in deaths of policy 1, 2, 7, and 8 do not go above 0.1 even, however, outliers in 4, 5, 6, and 9 are relatively high - even being higher than the ranges in the 75 policies.

The policies however are optimized for the worst ranges in A.1 and A.3 pfail values, while this graph shows outcomes across the full uncertainty space. It is noticeable that policies 1, 2, and 3 perform in a robust manner in deaths and damages. It is important to note that the total investment costs for policy 2 and 3 are relatively high, with policy 2 being the most expensive with 1.06e9 euro, which does fall in the low range of the sampled policies. Although Green Rivers will not pay these costs, it is important to keep emphasizing that a policy should be acceptable for all actors.

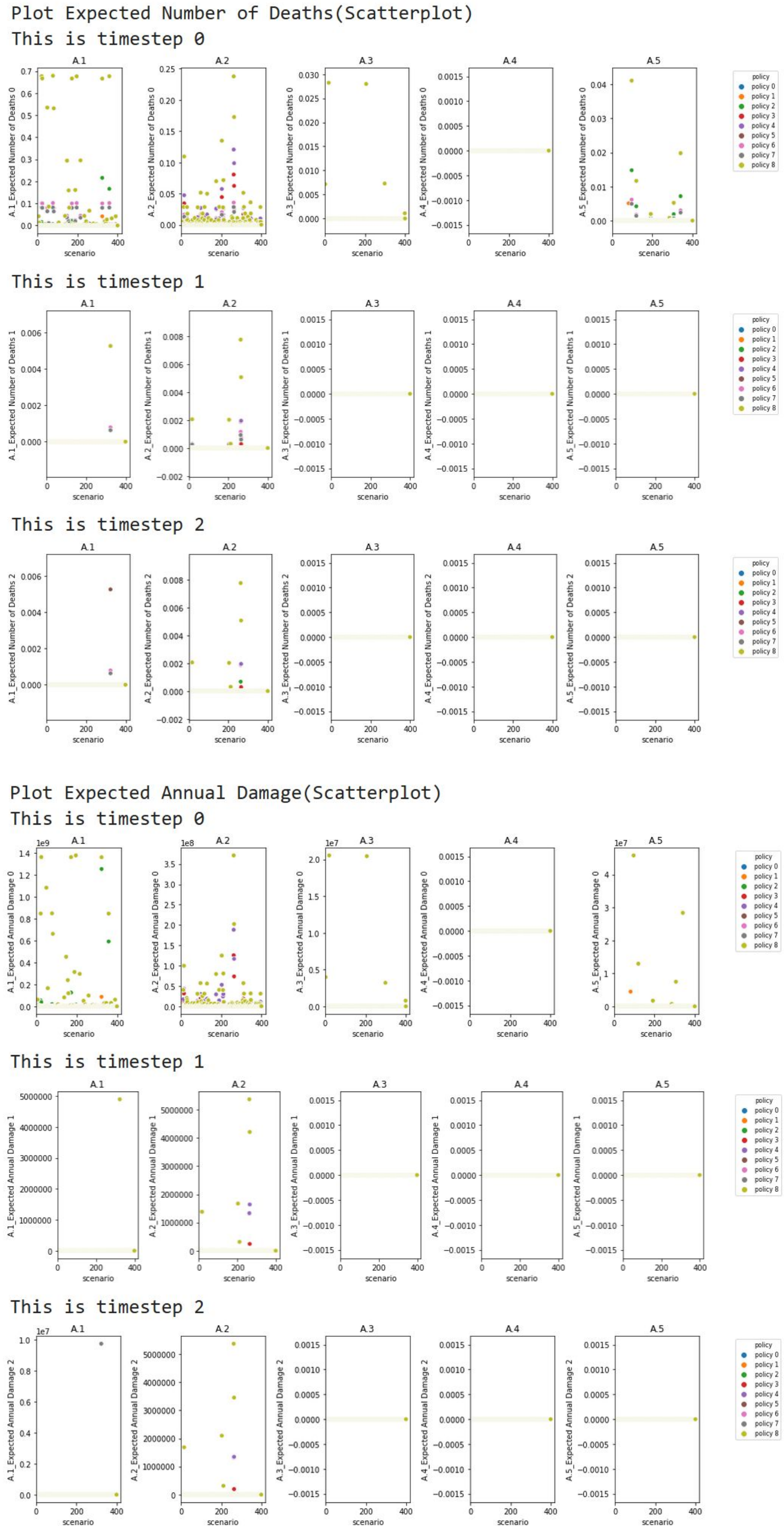

Figure 19. Scatterplots of policies in different timesteps in different locations per outcome.

The scatterplots in Figure 19 show several important implications for the policies. Outliers most commonly occur in A.1 and A.2. However, A.3 and A.5 are affected as well in the first time step. Another feature worth mentioning is that A.2 is affected in all time steps. When reviewing it is clear that policy 8 is not as robust as the other policies, due to the high number of scenarios in which the policy doesn't mitigate the damages and deaths. Other policies have outliers in specific locations, however it is not as systematic as policy 8. It is important to be mindful of these disadvantages as well for the final policy set. It is interesting to note that most outliers happen in A.1, while MORO has already taken the scenario space in which A.1pfail is low.

An inspection shows that policies from policy 5 and onwards do not include any Room for the River policies. These will not be taken into consideration as it does not help the biodiversity and nature areas in the IJsseldelta areas. Furthermore, in 2.4 it was clear that they have a relatively high interquartile range in damages. The downside to this decision is that all the low cost policies are disregarded.

Figure 20 and Table 10 show all the trade-offs for outcomes for the different policies that were found by MORO. The values between 0 and 1 represent the normalised robustness scores, which are based on the actual robustness scores from table 9. To be clear, these robustness scores are the product of the mean score per outcome of interest time the interquartile range, which is added to a fraction of the mean.

A clear trade-off can be seen between investing in Room for the River and investing in dike heightening. This makes sense, as implementing both will not have twice the effect.
Note that the vertical policy line in Figure 18 can be used to identify the policy in table 10, starting at 0 and going up to 8. This line should not be looked at when considering the outcomes.

Table 9. The robustness scores of all the policies as visualized in Figure 15.

	Damage Score	Deaths Score	Dike Invest Score	RfR Invest Score	Evac Score
0	1.964370e+14	1.861056e-06	1.196531e+18	1.178112e+16	3.252648e+08
1	1.133849e+11	1.143893e-07	1.196531e+18	9.305655e+18	0.000000e+00
2	7.853715e+11	9.160793e-08	1.196531e+18	6.272040e+18	1.574746e+06
3	1.964370e+14	1.292400e-04	1.196531e+18	1.178112e+16	0.000000e+00
4	1.980599e+14	1.307336e-04	1.196531e+18	7.906444e+17	0.000000e+00
5	4.577942e+14	3.845736e-04	1.501146e+18	0.000000e+00	0.000000e+00
6	4.577942e+14	8.652907e-06	1.501146e+18	0.000000e+00	2.928564e+08
7	4.577942e+14	5.537860e-06	1.501146e+18	0.000000e+00	4.520066e+08
8	1.161485e+15	7.686822e-04	1.196531e+18	0.000000e+00	0.000000e+00

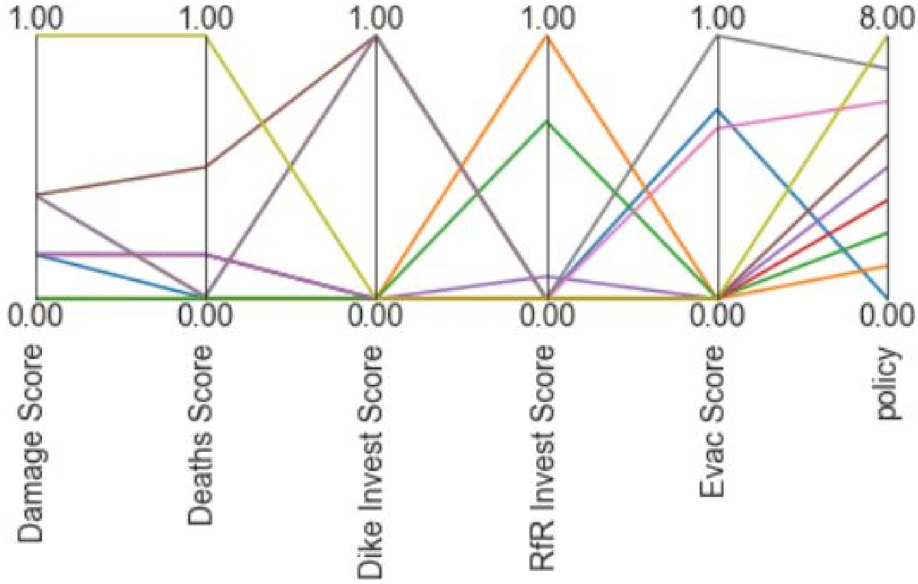

Figure 20. The visualization of the trade-offs in outcomes for the different policies.

Table 10. The normalized robustness scores of all the policies as visualized in Figure 15.

	Damage Score	Deaths Score	Dike Invest Score	RfR Invest Score	Evac Score	policy
0	0,169	0,002	0,0E+00	0,001	0,720	0
1	0,000	0,000	0,00E+00	1,000	0,000	1
2	0,001	0,000	0,00E+00	0,674	0,003	2
3	0,169	0,168	2,17E-01	0,001	0,000	3
4	0,170	0,170	1,12E-01	0,085	0,000	4
5	0,394	0,500	1,00E+06	0,000	0,000	5
6	0,394	0,011	1,00E+06	0,000	0,648	6
7	0,394	0,007	1,00E+06	0,000	1,000	7
8	1,000	1,000	2,11E-01	0,000	0,000	8

After removing the policies that did not make use of room for the river in any of the locations or timesteps, 5 policies remain that are considered optimal for the worst case scenarios. Figure 20 shows an overview of the locations and timesteps in which certain interventions take place in these optimal solutions. Note that room for the river is only being considered in locations A.1 and A.3. This again corresponds to the high impact a flood would have in these locations.The RfR policies show that RfR exclusively is not the best, it should be in combination with other measures such as an evacuation or dike heightening. Dike heightening is implemented in every location and time step except for A.2 last timestep, however the height increases are small (< 3 decimeters), although the dike increases are cumulative on a location the highest cumulative increase is 0.8 meters. All the policies are similar in the dike heights.

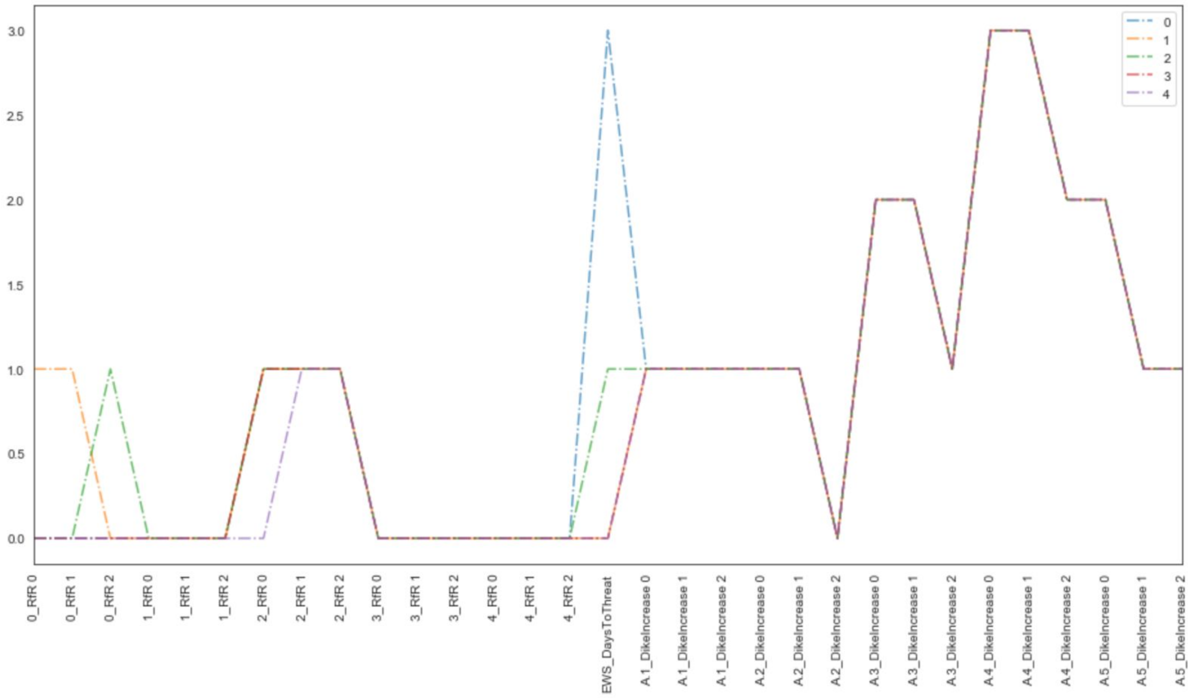

Figure 21. The 5 remaining policies and in what projects they invest.

These five policies are suitable for implementation in the IJsseldelta, however, as the scatter plots showed there are still scenarios in which these policies perform badly. Especially policy 4 and 5 might suffer from high number of deaths. The damages and deaths which occur with these policies in A.1 and A.2 in the first time step needs to be further analyzed, however, due to computational limits and time constraints a full MORO run cannot be done. Using feature scoring with the extra trees algorithm to classify the interested points as non-zero, it shows that the pfails in these locations are important uncertainties to run through in the next MORO iteration.

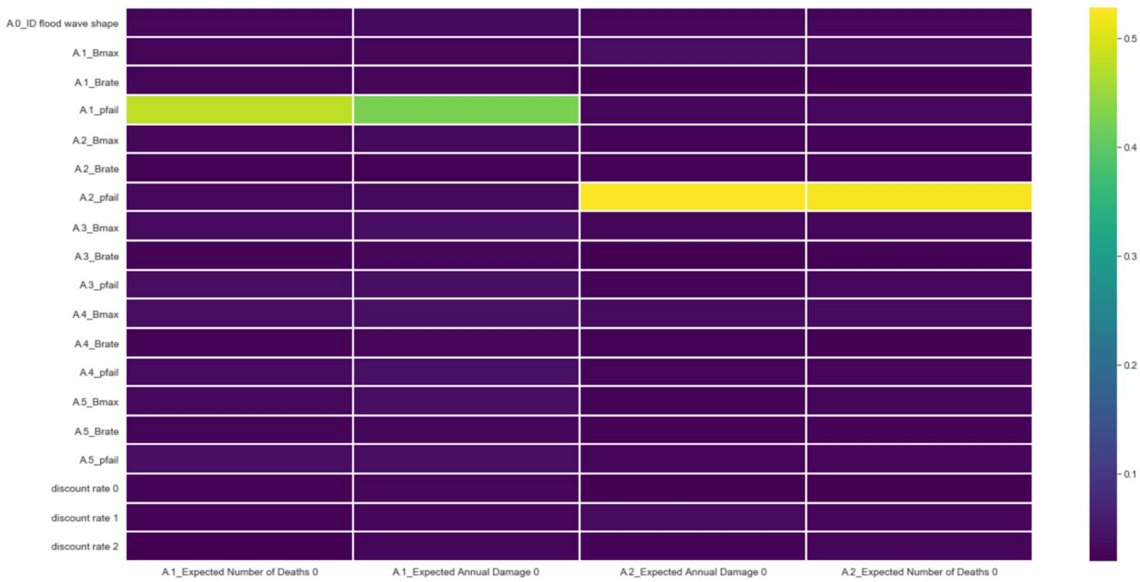

Figure 22. Feature scoring with extra trees.

6. Recommendations

In 2014, the Dutch government presented their general policy in the Natural Way Forward (Ministry of Economic Affairs, 2014). Since then, different government bodies have strived to recommend policies in which the importance of ecosystems and quality of natural areas is incorporated. This is also the case for the IJssel river area, where the impacts of climate change require solutions which preserve safety, mobility, and quality of life, while maintaining the functioning of ecosystems for important services.

The analysis in chapter 5 showed that doing nothing is much worse than applying random policies. Securing citizen safety and reducing property damage thus requires action. Robust solutions were however found to properly manage these objectives. The open exploration showed that the Doesburg and Zutphen regions were especially at risk of flooding. The found solutions were also most robust when it came to protecting these two seemingly vulnerable areas.

It is important to note that the investment costs were also minimized on. Even though Green Rivers won’t value this objective as much, it is likely to be an important objective for other actors in the decision making process. Investments in Room for the River are generally higher than for just dike heightening. As such other benefits of Room for the River should also be considered.

Given that Room for the River uses the existing nature and infrastructure for flood protection, there could be an opportunity to implement a solution which satisfies the interests and objectives of multiple stakeholders. As nature based solutions have also been on the political agenda for some time now, it can be stated that the policy, problem and solution stream are forming a policy window (Kingdon, 1993). After analysing Room for the River under different future scenarios, it became evident that the robustness of the configuration of Room for the River as formulated in the model depends on the exact location where it will be implemented. In some locations, Room for the River projects are robust and become optimal solutions in worst case scenarios.

However, it is highly likely that the net benefits from Room for the River are underestimated and are higher in reality. There are a few reasons for this underestimation. First of all, estimations of the benefits for biodiversity are often qualitative or ordinal expert opinions (CPB, 2019). This makes it difficult to incorporate biodiversity in the net changes in benefits of large-scale projects. In the case of the hydrological model for the IJssel river, the impact on biodiversity has been left out. Although part of the effect was implemented in the model, by making Room for the River alternatives less expensive, the impact is still not taken into account fully. In order to accommodate for biodiversity, it is necessary to propose quantitative measures which can provide a more complete insight into the net benefits of a project for other stakeholders. These measures can be incorporated in the model, or used as additional methods for the net benefit evaluation. CPB (2019, p. 8), the Netherlands Bureau for Economic Policy Analysis, has proposed the use of biodiversity points. Biodiversity points consist of several components:

- The area of natural or semi-natural ecosystems affected (in hectares or square kilometers),
- The ecological quality of each area, measured through a robustness score, and
- A weight factor per type of ecosystem, reflecting the contribution of the ecosystem to species richness at national, European, or global level, which depends on the species present in their threat level.

Biodiversity points make it possible to estimate the cost-effectiveness of alternatives. As an additional index with a specific focus on the average trend of species, the global Life Planet Index (LPI) can be used. This index is constructed by looking at trends of thousand of population time series (WWF & ZSL, 2018). Moreover, the importance of biodiversity and ecosystem services is often times underestimated because of the difficulty of engaging stakeholders involved. The two main reasons for this are (1) the presence of multiple, contrary perceptions of the impacts of ecosystem services on future generations and social values, and (2) whether stakeholders demand or supply ecosystem services, since this also impacts the interests that stakeholders have (Lienhoop & Schröter-Schlaack, 2018).
Stakeholders therefore do not always realize the embeddedness of biodiversity and ecosystems in systems of transportation and agriculture for example. It is therefore necessary to emphasise this embeddedness. There are multiple ways to communicate this embeddedness to stakeholders.

Considering the transport sector, not all configurations of Room for the River lead to the reduction of the water level. These different configurations have not been incorporated in the hydrological model, but it is important to stress that there are additional measures which can prevent hinder experienced by ships. Examples of these additional measures are constructing parallel dams and lowering groynes like Rijkswaterstaat did for the Waal river (Room for the River, 2015). The parallel dams and groynes influence the flow pattern of the river, and allow for better water drainage when there are high tides. Due to the structure of the parallel dam, the width of the current can also be regulated. This, and less sand nourishment, as a result of the dam, can reduce hindrance experienced by ships.

In Nijmegen, Kampen, and Arnhem, the benefits for spatial and economic developments due to Room for the River are also visible. Examples are new, modern agriculture facilities, profitability of hospitality arrangements, attraction of housing corporations due to riverparks, and an increase in river-dependent economic activities (Room for the River, 2017). Many indirect benefits of Room for the River for the quality of life therefore are yet to be assessed for the IJssel area.

In summary, it is important to come with a policy recommendation which accounts for the direct and indirect benefits of biodiversity. The current model does not incorporate all these benefits, and therefore, stakeholders have conflicting perceptions about the added value of biodiversity and with that, the added value of Room for the River. Through additional assessments and communication which do include these benefits, a more complete conclusion can be formulated.

7. Reflection

The actor we represented in the debate was an environmental interest group. For the debate we further specified this as a fictional organisation called “Green Rivers”. This was introduced and used throughout the report and is repeated here for clarity.

7.1 Tensions and Challenges Affecting the Recommendations

In a multi-actor arena, finding solutions to a problem is about more than optimizing goals, as it is not likely that a solution which is optimum for every stakeholder exists. Moreover, the uncertainty that is inherent with cross-border, multi-functional problems increases the difficulty of agreeing on a solution even more. Combining the multi-actor arena and the uncertainty on values shows that the IJssel delta can be seen as a problem with deep-uncertainty. This has a large impact on how the advice will be used in the decision making arena. As the involved parties do not agree on the specific problem at hand, the decision making process is likely to focus on defining the problem. A solution that seems optimal for one of the problem formulations, could be far from optimal in the problem formulation of another actor. This is a dangerous position to get into, as any value based decision can often be scientifically backed up (Sarewitz, 2004). A way to escape from this deadlock, is to broaden the agenda. Adding complexity to the system can create a situation where every actor can identify their important criteria in the discussion.

Perhaps even more important than consensus on the problem formulation, is providing attractive solutions for decision makers. Green Rivers’ position in the decision arena makes it an influencer instead of a decision maker. Even if policy is rational and effective it must still be attractive to implement from a political point of view. One way to block a policy is overwhelming public opposition. This is why science and policy should work not only towards the most optimal solutions, but also those solutions that are attractive in the current political climate.

Green Rivers must also position itself as a valuable ally in the decision making process. As Green Rivers is an interest group and not a decision maker, it can only attempt to have an impact on the decision making process. Other actors are likely to have their own analysis, and since analysis is never value free (Kettl, 2018), Green Rivers can do a better job of connecting with other actors by including the values of the other actors as well instead of only their own.

An additional challenge when dealing with a decision arena on a deeply uncertain topic is that it becomes more difficult to gauge other actor’s preferences. Uncertainty of possible or likely futures can change how other actors approach an issue, where the same issue in a case closer to full information often makes an actor’s preferences more static and predictable.

It is important for the model to be seen as trustworthy and reliable, if its results are to be pushed to influence the decision making process, or other actors will not be willing to accept any of the model's outcomes. It is also noteworthy to mention that the IJssel river model is very similar to a cost benefit analysis in its execution. Although this makes sense from a standpoint of optimizing the system, it is important to incorporate how punishing a cost benefit analysis outcome can be to specific actors. Such outcomes are more likely to find opposition from the actors that pay the biggest price. All actors should thus be focused on going from win/lose situations to more win/win outcomes to make all actors feel part of the negotiation.

On the other hand, it is not necessarily a problem for Green Rivers if the used IJssel river model's validity is questioned. The model's implementation of Room for the River solutions is limited as the potential economic and environmental benefits of Room for the River are completely neglected. As such, straying from the model to focus on the benefits of Room for the River beyond flood protection is a beneficial move. It is potentially hard to communicate with other actors such as the provinces when the aggregation level of the model is used. Provinces will be thinking about more than just costs and safety and more about the impact that the chosen solution will have on the local area and its residents. Also the time related aggregation creates difficulties in discussion, as other actors might care less about the timing of the implementation of a solution. Moreover, actors might not realize the potential benefits of biodiversity for their interests and objectives. Forgoing the model allows Green Rivers to connect with each actor on the matters that are truly important to them. This could help change the decision arena from us versus them to coalition building. If such a paradigm shift is possible, actors might be more willing to share information instead of withholding it. This in turn allows for more informed decision making for all parties.

7.2 Political Strategy

In order to deal with the complex situation in which Green Rivers finds itself, some political strategies must be utilised. Only then can Green Rivers maximize their impact on IJssel river policy. The first strategy that should be considered is an increase in complexity (Stirling, 2010). As was mentioned in chapter 6, the model that is used has important flaws that should be revised. By broadening the agenda with values such as biodiversity and mobility, the IJssel river area becomes more interesting for all parties involved. The differing perspectives on the situation will be less of a problem after raising the complexity. Even though Green Rivers prefers as much Room for the River as possible, compromises are likely necessary and such package deals are easier to achieve after raising the complexity.

Next to increasing the complexity of the situation, it can also be beneficial to prime the project, in order to draw more attention to it. From 2014, the Dutch government has been increasingly investing in nature-based solutions and climate change has become more and more current. When Green Rivers is able to couple concepts such as climate change, the governmental mandate and the protection of the environment to the Room for the River solution, there is an increased chance of success. Referring to the policy window (chapter 6) that is currently open (Kingdon, 1993), Green Rivers should frame the IJssel project as the perfect time to act (Tversky & Kahneman, 1985).

To make sure that Green Rivers is seen as an ally in the decision-making process, they should present Room for the River as an adaptive way of working. As the alternative has space for adjustments in the near and far future, it can be seen as more adaptive than the heightening of dikes. Together with the broadened agenda, this adaptive mindset will invite other actors to cooperate rather than to turn against Green Rivers.

7.3 Potential Risks of Strategy

When raising the complexity to get all actors involved, it is important that Green Rivers does not come across as too focused on its own objectives. Instead, the focus should be on other missing aspects of the model as well, such as mobility. The biggest risk to Green Rivers is that they are seen as an outsider to the project. As Green Rivers is not a decision maker in any of the potential arenas in the IJssel river project, the organisation must be able to show its value to the other actors or it might be dismissed. Green Rivers preferences should thus not be presented too aggressively as they can not negotiate from a position of strength.

Coupling solutions may be challenging as other actors may attempt to do the same with more success. An example could be transport companies coupling their objectives to governmental actors to take the focus away from environmental solutions. Rijkswaterstaat considers mobility to be a very important objective and will therefore be willing to cooperate with the transport companies as well. Also, coupling big issues such as climate change to the relatively small IJssel river, might induce the other actors to fulfill their environmental mandates in projects that can have a bigger impact.

Based on the model, costs for Room for the River are higher than costs for dike heightening. Even if other actors like the solutions that Green Rivers brings to the table, these solutions might still not be feasible, due to the costs of the implementation. In this case it will be hard to get Room for the River implemented. Focusing on quantifying benefits, as discussed in chapter 6, is then the only approach. It is likely that heavy compromising on the part of Green Rivers will be necessary in such a case.

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