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Room for the River Analyst Deventer

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To Do list

1. Summary

   Complete summary has to be written (1 page) - **Emanuel**
   Chapter has to be checked (rubric + grammatical) - **Lian**

2. Problem framing

   Chapter has to be checked (rubric + grammatical) - **Robyn**

3. Methodology

   Small indirect search part needs to be written - **Robyn**
   Global Sensitivity analysis part needs to be finished - **Emanuel**
   Maybe a small extension of the current search method descriptions? - **??**
   Chapter has to be checked (rubric + grammatical) - **Robyn**

4. Results

   Opening part needs to be written - **Robyn**
   4.2 Global Sensitivity Analysis needs to be written - **Emanuel**
   4.5 MORDM needs to be written - **Noah**
   Chapter has to be checked (rubric + grammatical) - **Emanuel**

5. Conclusions

   Conclusion introduction - **Emanuel**
   Conclusion on open exploration - **Ricardo**
   Conclusion on Global Sensitivity Analysis - **Emanuel**
   Conclusion on scenario discovery - **Robyn**
   Conclusion on feature scoring - **Lian**
   Conclusion on MORDM - **Noah**
   Chapter has to be checked (rubric + grammatical) - **Robyn**

6. Discussion

   Discussion - **Lian** + **Noah**
   Chapter has to be checked (rubric + grammatical) - **Emanuel**

7. Political reflection

   Complete Political reflection (2 to 5 pages) - **Cecile** + **Ricardo**
   Chapter has to be checked (rubric + grammatical) - **Lian**

8. Fix all notebooks + markdown - **EVERYONE**

1 Summary

The Netherlands is situated in a delta of four major European rivers: the Rhine, Maas, Schelde and Eems. The Rhine cuts right across the Netherlands and branches as the IJssel River which flows north for about 125 km before discharging into the IJsselmeer [5]. As 25% of the Netherlands is below sea level, increase in water levels due to a myriad of factors possess the risk of flood. Historically, flood protection policy in the Netherlands has been based on construction of dikes and the paradigm of regular increase and strengthening of these dikes whenever the Netherlands assessed an insecurity or safety concerns linked to flood risk[8]. Climate change and associated rise in sea levels coupled with geographical location of the Netherlands possess new flood risks which cannot be continuously resolved through increase in existing structural flood defences mainly consisting of dikes. As is characteristic of water network systems, building dikes affect the flow of water both upstream and downstream. Dikes reduce also the room need by run-off rainwater and as such the cross section of rivers are narrowed. This has the side-effect of higher water levels which dictates the use cases of the river. Furthermore de Bruijn et al.(2015) point out that "Interaction between catchment areas can be sequential and parallel. In all these mechanisms there are also uncertainties concerning precipitation, transport of clay and sand, and flood volumes".

A novel policy paradigm was introduced through the government program 'Room for the River' which, as evident in the naming, gives room to the river as opposed to the dikes which constrict the river space. The key of the Room for the River approach is to restore the river's natural flood plain in places where it is least harmful in order to protect those areas that need to be defended. Klijn et al. (2018) argue that although the program is regarded as being a success from several perspectives, it remains debatable if it has achieved its prime goal in reducing flood risk. As evident, the associated risk of flood and uncertainties cannot be diminished and must be assessed to adequately make policy decisions and future investments as part of continued flood protection programs. This needs to be done in order to minimize mitigating effects of floods posed to municipalities along the IJssel River. The deep uncertainty surrounding the problem as well as the diverse stakeholders involved could be explored using exploratory model analysis.

Outlined in this report, is the assessment of flood risk management plan for the Deventer municipality, the problem owner whose primary concern is the safety of its ca. 80.000 citizens. The analysis was conducted as part of the Model-Based Decision Making course held in the fourth quarter 2022 at the Delft University of Technology. After assessing the problem, several recommendations were made in the assigned role of the authors as Analysts for Deventer.

Primarily, the municipality of Deventer could invest in dikes reinforcement as well as in Room for river costs as this would surmount in the least amount of damages in the occurrence of a flood event. However, the municipality must monitor policy decisions of other municipalities along the IJssel as these indirectly have an influence on the areas of interest and importance to the municipality. Based on the insights from the sensitivity analysis, several factors that influence the number of casualties and damages in the occurrence of a flood event need to be taken into consideration in policy decision. It is indeed necessary for the municipality of Deventer to actively include other dike rings and associated municipalities as part of its policy decisions in order to achieve null casualties and minimal damage in the event of a flood. Negotiation and dialogue should take place with municipalities of significant influence whose flood risk management policies conflict with the main goals and objectives of Deventer. The goal of this negotiation is to protect the interests of Deventer and its inhabitants.

To achieve its safety interests, Deventer is best positioned by investing in the room for river program. This is coupled with significant cost in order to achieve "zero" casualties to the municipality. A multi-scenario MORDM showed that all best performing and most robust policies for Deventer involve at least as much, if not more action from the other cities. If sufficient collaboration can be achieved, the Room for River program combined with the traditional strengthening of dikes in all 5 cities is considered to be the best strategy the municipality could pursue in achieving its intended goals, along with a early warning system of 3 days. The key location for widening the river, given the costs and expected deaths in Deventer, is in Gorssel. Furthermore, no budgetary constraints or considerations were taken in the analysis that was performed. Such constraint could play a role in the analysis and could influence the decision making.

Finally, our paper will reach a conclusion in which we **advice Deventer to strive for dike hightening in all cities, and have Gorssel make Room for the River against a fair compensation. It will also be adviced to set early warning systems of 3 days.** This solution sufficiently considers and benefits the other stakeholders involved in the project.

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2 Problem framing

Before being able to give the municipality of Deventer advice on the decision-making process, it is important to understand which stakeholders are involved and in which political arena it is operating. The next sections will give a detailed explanation of this deep-uncertainty problem and look into the (different) objectives, beliefs and values that Deventer has to take into account. This is an important step in preventing conflict.

2.1 Introduction

Within the Netherlands, flooding has been a severe threat for many years [42]. Mainly because a big part of the country, about 25%, lies below sea level [24]. An example of catastrophic flooding is the "Watersnoodramp", which happened in the year 1953. Due to multiple coincidences, the sea-water level rose 4 meters above the Amsterdam Ordnance Datum and dikes broke in more than 150 cities and towns. This resulted in 1836 deaths and over 1.5 billion guilder damage [25]. The Dutch government restored all the dikes in a short period but also started to strongly improve them in the following 40 years to make sure that a tragedy like this would never happen again. Resulting in a lot of expertise in water management, which is becoming more relevant every day with the current rising sea level [42].

A currently ongoing water management project in the Netherlands is 'Room for the River' (RfR). Due to climate change, the occurrence of unusual frequency & periods of rain- and melting glaciers raise the water level of the seas and subsequently rivers. To counter this effect, the RfR project will widen the boundaries of rivers to transport more water instead of only improving the dikes [27]. The Ijssel is a river in the Netherlands with a high flooding risk [9] where this new strategy needs to be applied [27]. This river of 127 kilometres is a branch of the Rhine and flows through Zutphen, Deventer, and Kampen to the IJsselmeer [26]. While it does so, it crosses multiple different municipalities, both rural and urban, which creates a situation where there are different interests of a large and diverse set of stakeholders.

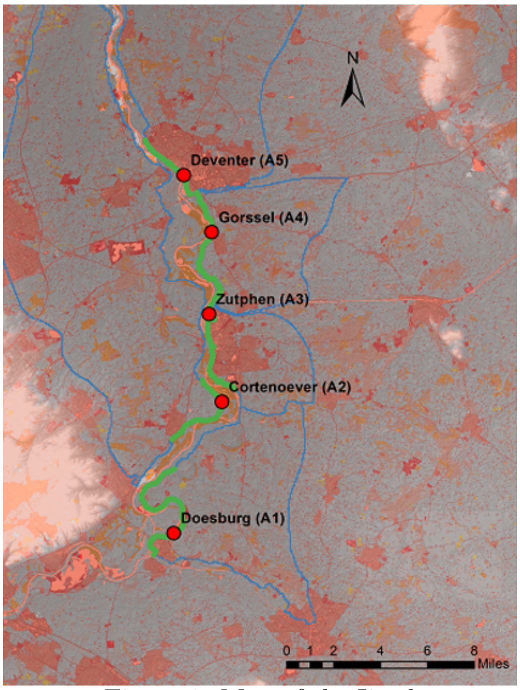


Figure 1: Map of the Ijssel

One of the main reasons the project "Room for the River" was initiated was that since climate change will cause more uncertainty about the amount and occurrence of rain- and melt water [27]. Next to that, the changing climate leads to other effects like a higher sea level, more and heavier storms, but also things that can not be foreseen at this point [35]. If these different phenomena occur simultaneously by chance, this can lead to extreme situations like the Watersnoodsramp. Walker et al. (2012) describe a situation like this as level 5 uncertainty, where the context of a system has an unknown future. Because the future context is highly uncertain, system outcomes also become increasingly uncertain. When the borders of the Ijssel are extended, for example, the water will flow differently [32]. Estimations can be made about the different effects this has on the overall water flow, but under unknown conditions, things can turn out completely different than expected. Next to that, the Ijssel is used in a lot of different ways, by different actors in different municipalities, both upstream, as well as downstream [32]. The effects of interventions can not be foreseen for all these different use cases of the stakeholders, which creates uncertainty of at least level 4 [39]. In addition to this, with the great amount and diversity of stakeholders involved, it is also hard to decide how to value different system interventions and outcomes. Especially when certain outcomes are positive for a particular stakeholder but directly conflict with the interests of other stakeholders, political conflicts can arise [8]. When the borders of the Ijssel are changed upstream, this has its effects on the water flow downstream. On its own, this affects all the different stakeholders not only on usability but also on safety. Together this leads to an uncertainty level of at least 4 [39]. Concluding on the diverse range of stakeholders and the level of uncertainty in the 'Room for the River', this case can be marked as unstructured with deep uncertainty.

To deal with this deep uncertainty, Exploratory Modeling Analysis (EMA) can be very helpful. EMA is a research methodology that allows researchers to analyze complex systems with high levels of uncertainty. The main focus is on running computational experiments to support decision-making [18]. With the help of this tool, potential solutions can be explored by testing different sets of uncertainty inputs on a variety of different models [20]. By using a wide variety of future system conditions, this could then be used to formulate well substantiated policy advice for the explored stakeholder objectives [19].

Within the rest of this report, EMA is used to find the desired results. To do so, the last two sections of this chapter dive deeper into the problem owner and explore the political arena for this problem. Within chapter 3, different research tools are presented which are going to result in a broad range of outcomes presented in chapter 4. In the following chapter 5, multiple limitations will be discussed and future research recommendations will be done. Finally, conclusions are drawn based on the results and the knowledge of the problem. In addition to the report, in chapter 7 a political reflection has been written about the real-life experience of the different interests of parties during the debates.

2.2 Problem owner: Deventer

This report is created to develop a flood risk management plan for the upper branch of the Ijssel River. By flood risk management, preventing floods and limiting the damage thereof is intended. The problem owner for whom this report is written is the municipality Deventer. Deventer is one of the five locations of interest that lies near the river and is a major urban area that aims to protect its citizens from floods.

Deventer is a lively city located along the Ijssel with a historic city centre. The city counts ca. 80.000 inhabitants, a university, and is home to multiple start-ups [13]. Deventer's main objective in the 'Room for River' project is to preserve the safety of its citizens. It strives to set policies that protect the security of people and limits the damage during potential floodings. Deventer believes that the flooding in the city is more harmful than flooding in rural areas, which is why controlled flooding in less densely populated areas is preferred. Evacuation of relocation should be avoided according to Deventer, as the city is built on its history and traditions.

Deventer is represented by the province of Overijssel. The province also represents the interests of other parties, which is important to keep in mind.

2.3 Political arena

For Deventer to achieve its goal of protecting her historic city centre and assure the well-being of her inhabitants (physically as well as economically), it is important to understand the political arena. Knowledge of the political arena of the problem brings awareness of other stakeholders' positions and interests and can help in overcoming obstacles and preventing conflicts.

The arena of the Room for River problem counts 10 main actors which each have their resources, goals, and interests. All actors will attempt to guide the policy to become most convenient for them. The main similarities and differences between the objectives of all the stakeholders will be discussed in the next paragraph. For a more detailed overview of the interest of the actors, see appendix A.

Main stakeholders in the Room for River decision arena:

- Rijkswaterstaat
- Delta Commission
- Transport Company
- Environmental Interest Group
- Province of Gelderland
- Province of Overijssel
- Dike ring 1 & 2 - Doesburg & Cortenoever (rural)
- Dike ring 3 - Zutphen (urban)
- Dike ring 4 - Gorssel(rural)
- Dike ring 5 - Deventer (urban)

All stakeholders share the main objective to prevent the flooding of the Ijssel. However, on the question of how to prevent this flooding differentiation exists amongst the actors.

The main objective of the Rijkswaterstaat and Delta Commission is to prevent the flooding of the Ijssel and assure a smooth course of action for the project. Especially Rijkswaterstaat aims to include all stakeholders and maintain a safe situation surrounding the IJssel. The different dike rings are smaller cities along the Ijssel that have slightly different interests at hand. The urban areas (Zutphen and Deventer) emphasize protecting their inhabitants and preserving their historic city centres. The more rural areas (Doesburg, Cortenover, and Gorssel) put priority on continuing agricultural activities throughout the entire year, and therefore support controlled flooding of outside areas. These areas are represented by the Province of Gelderland and the Province of Overijssel. However, both provinces represent one rural and one urban area, which have conflicting goals. Therefore, it might become difficult for the provinces to take a clear stance in the debate. Furthermore, the transport companies' main objective is the continuity of shipping on the IJssel waterway. To achieve this, the Ijssel must at minimum be 4 meters deep. Finally, the environmental interests groups strive for a diverse and healthy environment for animals and humans.

Understanding the differences in objectives amongst the players can be useful for Deventer before going into the decision-making process. During the debate, Deventer is represented by the province of Overijssel, which also represents Gorssel. Between Gorssel (a rural area) and Deventer (an urban area), disagreement exists on the best solution for 'Room for river'. As Deventer is not the main stakeholder and not directly present during the debate, chances are that Deventer will have to make compromises. Knowing the interests of other stakeholders can help in estimating which favorable (and for Deventer preferred) potential compromises exist.

3 Methodology

This chapter dives deeper in the theoretical part of analysing the Room for the River case with the help of exploratory modeling. As mentioned in the previous chapter, there is a lot of uncertainty in the Room for River case which leads to deep uncertainty [39]. Moreover, the large amount of stakeholders with different interests makes it even harder to select the right policies. To tackle this deep uncertainty, a model of the Room for the River project on the Ijssel has been used [15]. This model can be used in combination with exploratory modelling using the EMA workbench to explore different scenarios.

The EMA workbench makes it possible to run a very broad range of experiments on a very large scale, based on a single model. Within this chapter, two different groups of analysing methods are presented, Open Exploratory and Directed Search. These two groups of analyses can be used to explore the results from the model with the EMA workbench. The analysis tools are briefly discussed using existing literature before they will be performed and discussed in chapter 4.

3.1 Open exploration

The first analysis that is performed is open exploration. This analysis method uses computational experiments to assist in system understanding in cases of significant uncertainty [1]. Open exploration is often used for identifying of different types of model behaviour and the identification of bandwidth outcomes [17]. Using the EMA_workbench, a simulation model is constructed consisting of 750 scenarios and 40 policies. This results in a total of 30.000 experiments. The scenarios and policies are generated using the Latin Hypercube sampling method. With these experiments different types of analysis can be performed to explore the results and get a better understanding of the data set.

3.1.1 Visual Analysis

When all the runs have been executed, it is important to visualize them. The different outcomes of the experiments will be plotted against each other to find a relation between them.

3.1.2 Global sensitivity analysis

"Global Sensitivity Analysis (GSA) [34] attempts to provide a 'global' representation of how the different factors work and interact across the full problem space to influence some function of the system output" [30]. The GSA carried out on the formulated problem seeks to determine how specific outcomes for the municipality of Deventer are affected by certain features surrounding the problem. Features of the EMA Workbench utilizing the variance-based sensitivity analysis (Sobol method) were employed in this study. Based on the Sobol method, the sensitivity and interactions of distributed flood forecasting model parameters with and without accounting for correlation could be analyzed. This helps create an insight into how outcomes may be affected depending on policies that lean heavily on specific factors that are relevant in the flood risk management pertinent to the problem owner-Deventer. Pertinent in this analysis were principal values that the problem owner highly prioritizes in its objectives as previously discussed.

3.1.3 Scenario discovery and Feature Scoring

The third analysis is scenario discovery. This analysis method is applied to the data set that was constructed in the open exploration. Scenario discovery is a form of exploratory modelling aimed at identifying input spaces that result in outcome spaces of interest [3]. The Patient Rule Induction Method (PRIM) algorithm, which is incorporated in the EMA_Workbench is used as the scenario discovery method. This is the most commonly used scenario discovery method, it uses a lenient hill climbing optimization procedure to seek a set of subspaces in the uncertainty space in which the value of a given output variable is significantly different from the average value of this variable over its entire domain [21]. The PRIM algorithm is very interactive and provides useful visualizations that help the user balance the three scenario measurement variables: coverage, density and interpretability [3]. Feature Scoring will be performed to analyse the most relevant feature within the model. Here the impact of the different cities cities on each other will be examined [18].

3.2 Directed search

Directed search is a term that describes analyses designed for supporting robust decision-making. The directed search method is well suited for worst case discovery and identifying boundaries where behaviour switches [33]. There are three approaches to conducting a directed search, Many Objective Robust Decision Making (MORDM), Multi-scenario MORDM and Many Objective Robust Optimization (MORO) [2]. In light of the findings presented in Bartholomew & Kwakkel (2020), this study chooses to use the multi-scenario MORDM approach. Multi-scenario MORDM strikes a nice balance between optimality and robustness, while also only requiring a modest computational cost compared to the normal MORDM [2].

Multi-scenario MORDM is an extension of MORDM. Multi-scenario MORDM uses several different reference scenarios and executes optimization for each scenario. The use of multiple scenarios, in contrast to MORDM which only uses 1 reference scenario, leads to a more diverse set of decision variables and better policy performance under extreme conditions [41].

The Multi-scenario MORDM consists out of four stages [41]:

1. Problem formulation
   In this stage, the system elements and decision objectives that will be included in the model will be determined. These elements and objectives can be found in 4.4.1.

2. Generating alternatives
   The generation of alternatives will be done with the help of the ϵ-NSGA2 MOEA (Many Objective Evolutionary Algorithm). This algorithm finds a set of pareto optimal alternatives, which can be used further in the Multi-scenario MORDM. The generation of alternatives will be done for 3 different reference scenarios, the 3 scenarios will be presented in chapter 4.4.2.

3. Uncertainty analysis
   The large number of candidate solutions (alternatives) generated in step 2, will be filtered using a set of constraints. This leads to a smaller set of candidate solutions per reference scenario, which will then be re-evaluated under uncertainty [22]. After running additional scenarios for each of the candidate solutions, the robustness of these solutions will be evaluated. This will be done with a signal-to-noise ratio analysis and a maximum regret analysis.

4. Scenario discovery
   Finally, the set of candidate solutions used in step 3 will be analysed in a scenario discovery. In this 4.4.4, the PRIM algorithm will be used to seek a set of subspaces in the uncertainty space in which the value of a given output variable is significantly different from the average value of this variable over its entire domain [21].

4 Results

In this chapter, the results from all the different analysis will be discussed and elaborated. First, in Open Exploratory, in order to get a general idea of the behavior of the model and which factors influence each other in what way. After that the MORDM, to find fitting solutions for the Municipality of Deventer. This last analysis will lead to policy advice.

4.1 Open exploration - Visual Analysis

The first method executed is Open Exploration, which will be performed as described in section 3.1. For this exploration, 40 potential policies are tested based on 750 different scenarios each. These results are then combined and shown in multi-scatter-plots, which show outcomes of the policies for the most important KPI's of Deventer. The results for Deventer are presented and discussed in this chapter, while the scatter-plots for other actors are given in appendix 7.4.

- Expected annual damage in Deventer
- Expected causalties in Deventer
- Dike investment costs in Deventer
- Evacuation costs for Deventer
- Room for the river costs for Deventer

Figure 2 shows scatter-plots for each pairing of the variables and histograms for the plots along the diagonal. As earlier mentioned, the plot shows the effects on the five most important KPI's for Deventer. A few conclusions can be drawn based on the scatter plots, these will be listed and explained below:

1. When more money is invested in dikes, the expected damage goes down. This can be seen on a much denser distribution of the points in the scatter-plot when dike investment increases.
2. When total expected damage increases, two different trends are possible according to the total amount of expected deaths. It is possible that for an increase in expected damage the total amount of expected deaths increases slowly or more strongly.
3. When the total amount of evacuated people is zero, this could lead to a very large amount of deaths. But when people are evacuated, the amount of expected deaths will stay relatively low.
4. When there is a larger amount of expected damage, the model shows also an increasing trend on people being evacuated.

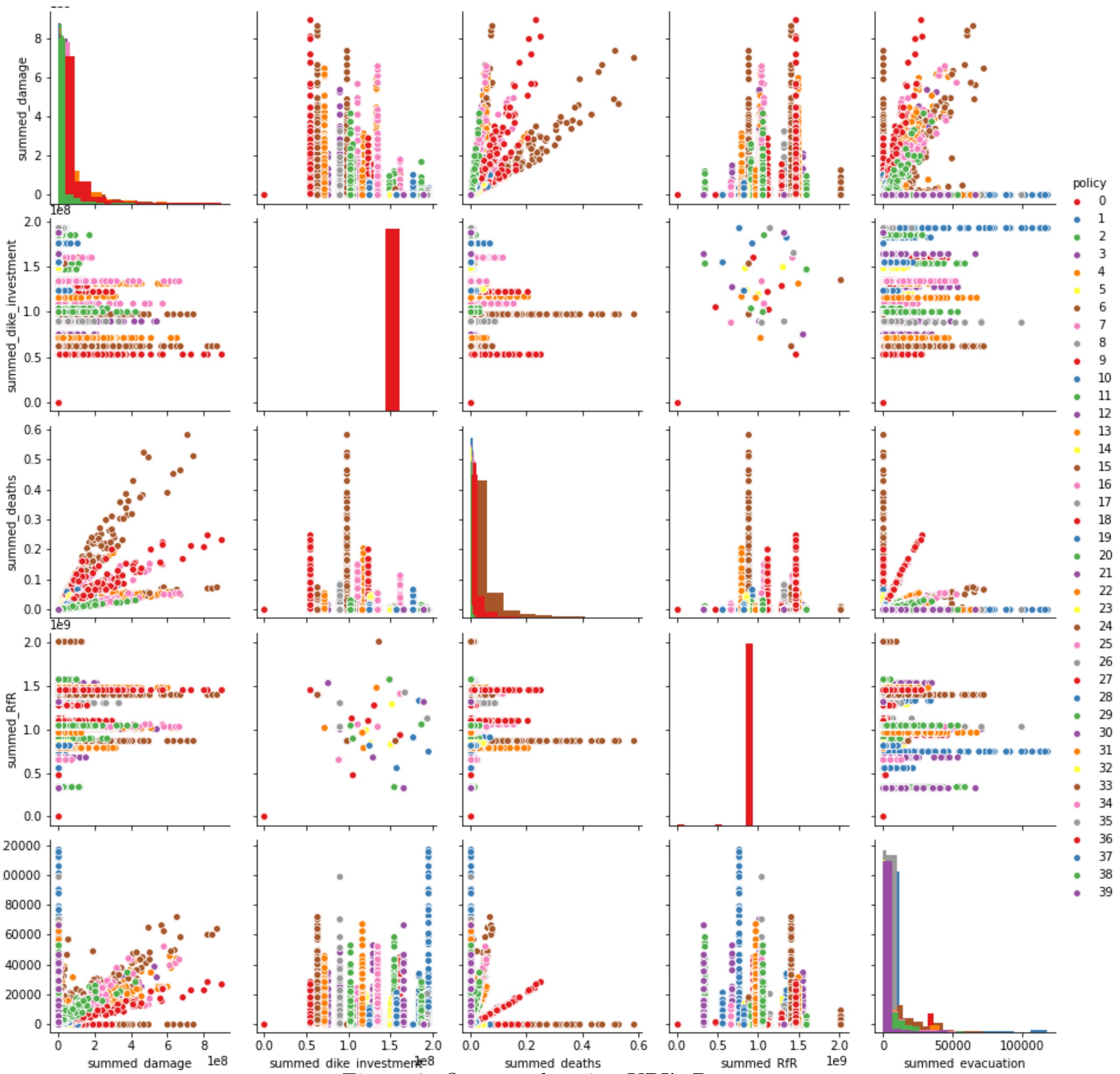


Figure 2: Open exploration KPI's Deventer

4.2 Global Sensitivity Analysis

Sobol' method is one of the widely used global sensitivity analysis methods based on variance decomposition [40] and was employed in the GSA of this study. In the analysis of the uncertainties pertaining to the problem, extreme cases were considered and utilized in developing the base scenario. In the primary simulation, the worst case scenario based on the number of total cost was investigated. Thereafter, further experiments based on worst case scenario was considered for aggregated deaths, evacuation and dike investment pertaining to the problem owner. Although other sensitivity methods are embedded within the EMA Workbench, computational constraints limited the possibility of exploring several methods to gain aggregated insights on the problem. Nonetheless, the conducted study revealed relevant insights on the interactions of the parameters and effects on the outcome.

4.2.1 Deventer Expected number of deaths

As safety of its citizens is paramount to the municipality. The expected number of deaths cannot be discounted in the event of a flood and factors involved play a active role in uncertainty analysis. In the conducted analysis, failure of the dikes is perceived to be the chief parameter involved in the outcome of expected number of deaths. However, that pales in significance when considering the significance of breaches of other dikes within the network.

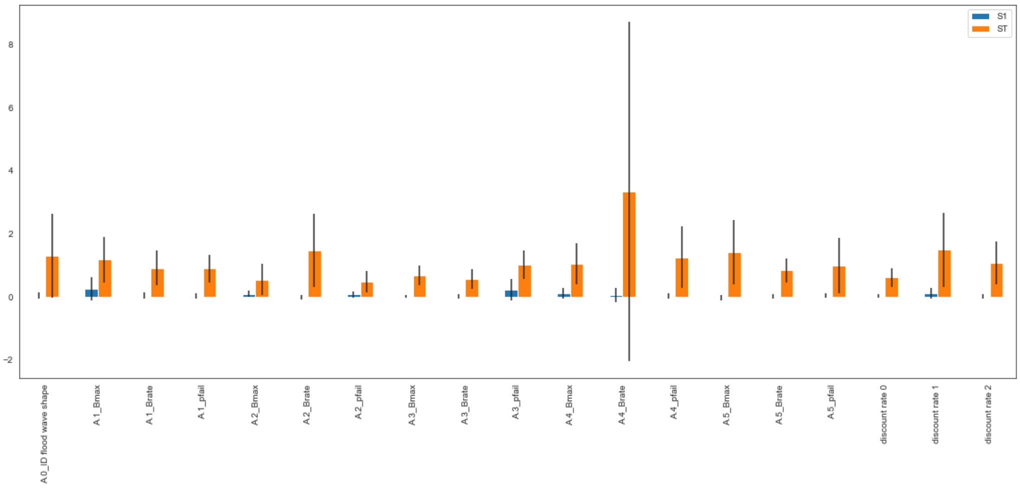


Figure 3: Sensitivity Graph Expected number of deaths

4.2.2 Deventer Total costs

As can be observed from Figure 4, several in factors play integral roles in the total cost factor. The most significant factor is the failure of dikes in other locations along the IJssel river. Although Brate of Dike ring 4 (rural) seems to contribute mostly to the total costs, the significance can be largely discounted.

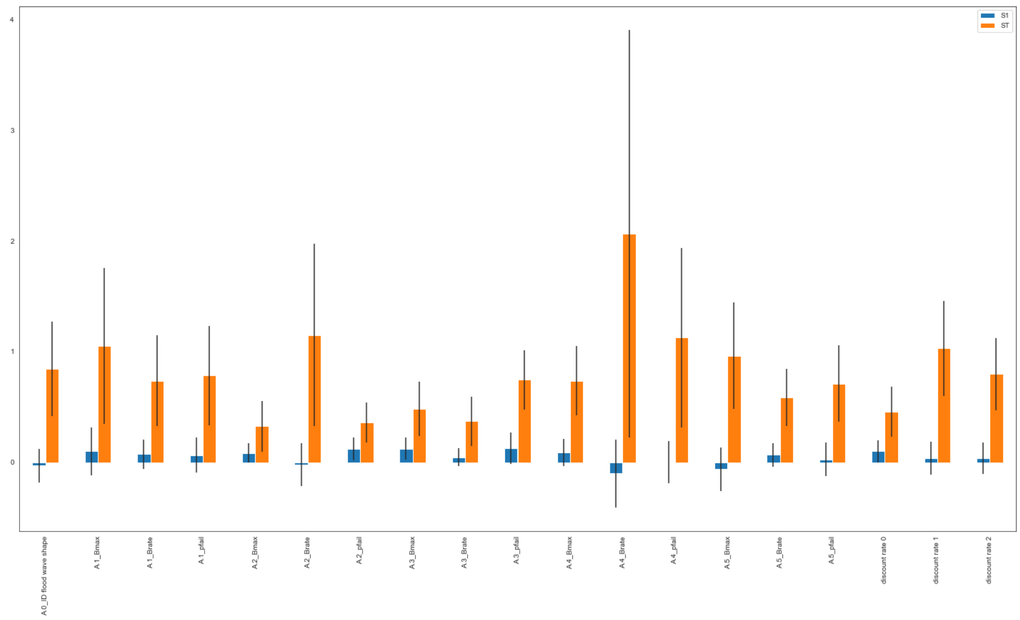


Figure 4: Sensitivity Graph Total Costs

4.2.3 Deventer Expected Evacuation costs

Paramount to the problem owner is the safety of its citizens and evacuation of citizens as part of flood risk management cannot be discounted in the analysis. Suffering casualties can be considered as a taboo choice that would be avoided with significant priority. In the figure 5, it can be observed that the dike failure in the other dike rings play active roles in the evacuation costs in the event of a flood. As such, the municipality is not isolated in it's policy decision regarding flood risks and needs to actively involve other municipalities as part of its policy goals and pursuits.

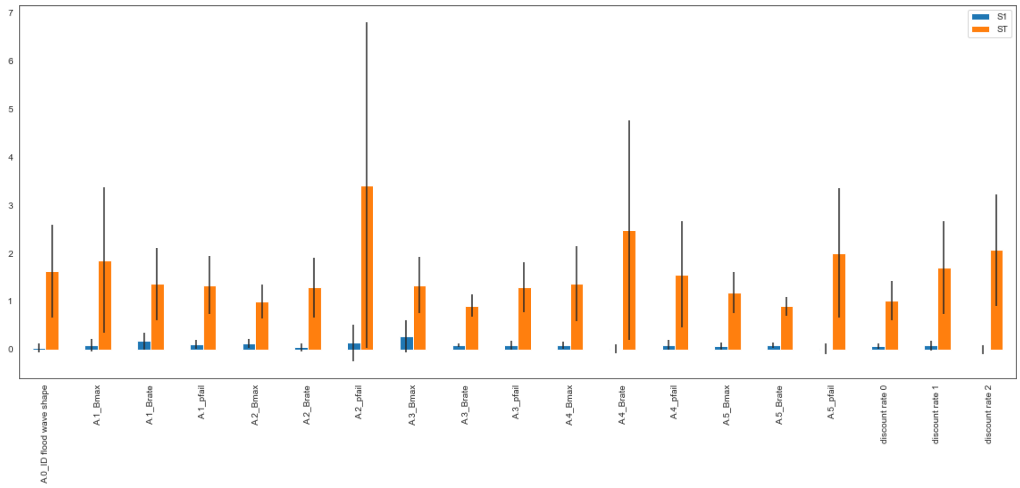


Figure 5: Sensitivities Evacuation Cost

4.2.4 Deventer Room for River Costs

Room for River takes into account the hydrographic interactions between linked water bodies. Flood risk strategies identified neglecting these interactions seem to equally distribute risk[4]. As evident from the distribution above, analysis of costs relating to RfR costs is not primarily dependent on any of the parameters involved in flood risk. This is in line with the reasoning that Room for river adopts a different perspective approach as opposed to traditional physical defence systems involving dikes or that no policies for RfR were implemented.

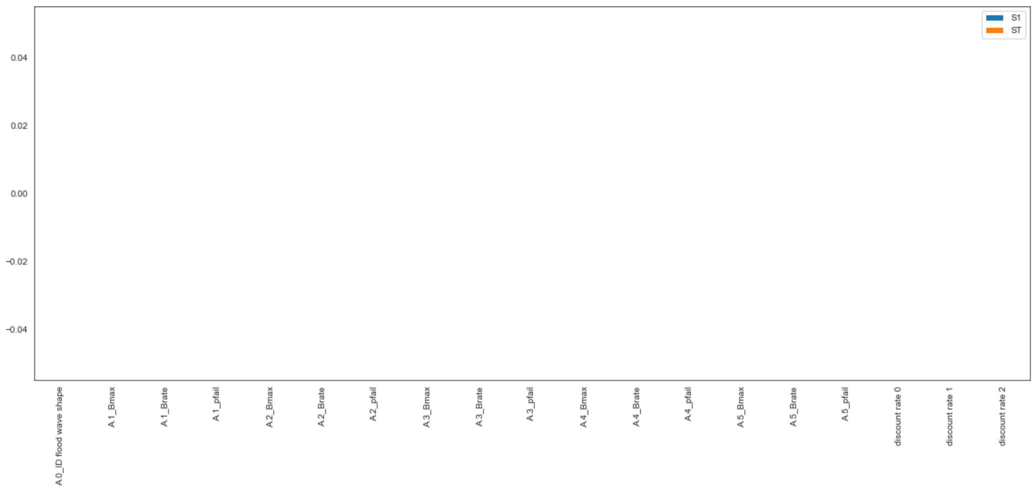


Figure 6: Sensitivitites Room for River Total costs

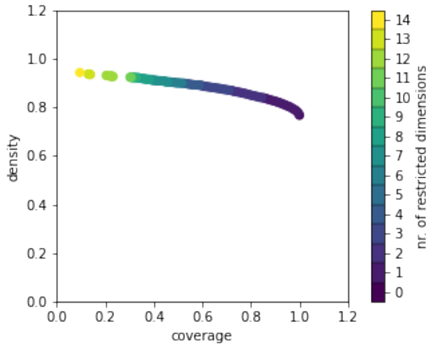
4.3 Scenario Discovery

To set up the PRIM algorithm, the peel-alpha and minimum coverage threshold parameters have been assigned values of 0.01 and 0.8 respectively [3][16]. The peel-alpha parameter determines the amount of data that is peeled of in every iteration of the algorithm. The minimum coverage threshold of 0.8 indicates that the final box the algorithm finds has to contain at least a fraction of 0.8 of cases of interest [16]. PRIM produces a better description of the data than CART for all outcomes of interest. Therefore, PRIM was used for the complete Scenario Discovery.

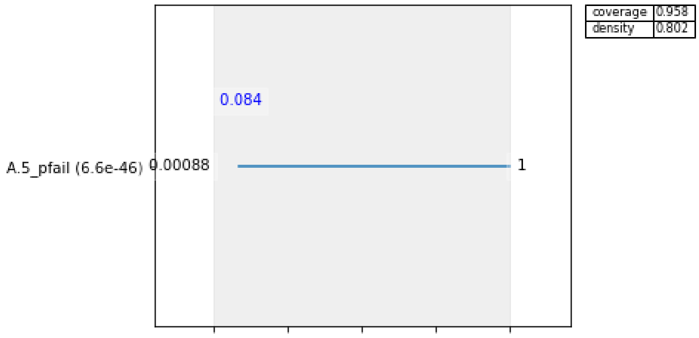
The output space of interest is determined by the interests of the municipality of Deventer. These interests are: *A5_ Expected Annual Damage, A5_ Expected Number of Deaths, A5_ Dike investment Costs, RFR Investment Costs* and *Evacuation Costs*, as defined in 4.4.1. The municipality explicitly mentioned that *A5_ Expected Annual Damage, A5_ Expected Number of Deaths* are the most important to consider. Therefor, these two interest will be discussed.

For all the interest a value is chosen for which the outcome will be evaluated, based on the interest of the municipality of Deventer. They indicated that damage and the number of deaths should be limited at all time, even if this would cause a bigger investment. That is why the *A5_ Expected Annual Damage* $< 5 *10^6$ and *A5_ Expected Number of Deaths* $< 10^{-6}$.

To evaluate the results of the scenario discovery, there was searched for cases (boxes) with a coverage of at least 0.80. These were are compared and looked for the case with the highest corresponding density.
Figure 7a illustrates the trade-off between coverage and density for the expected number of deaths cases. As explained, there is decided to further inspect the case that has a minimum coverage of 0.8 with the highest density. Figure 7b shows the visual format of the inspected case. From this there can be concluded that dike failure in Deventer is the most vulnerable uncertainty when it comes to number of deaths in Deventer.
Figure 8a shows the trade-off between coverage and density for the expected annual damage. For this outcome, case 7 was inspected for the same reasons as explained for expected number of deaths. Figure 8b is the visual format of inspected case 7. From this figure there can be concluded that dike failure in Deventer is the most vulnerable uncertainties when it comes to the expected annual damage in Deventer.

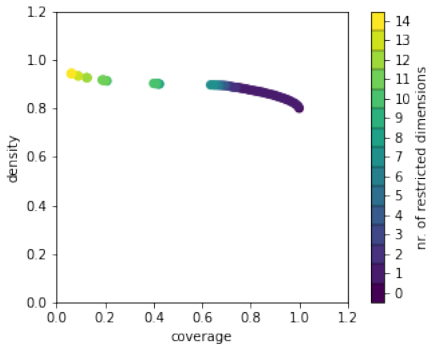


(a) Trade-off coverage density summed deaths

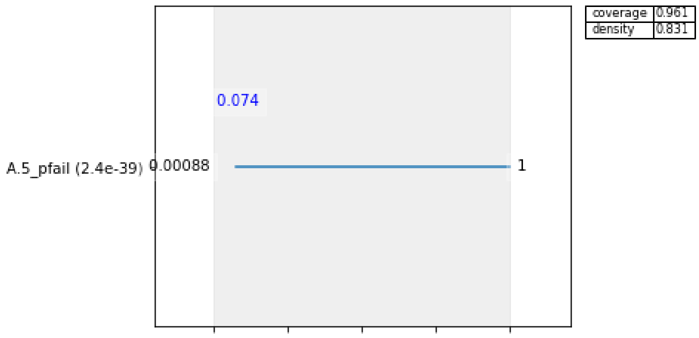


(b) Results of PRIM case 3 summed deaths

Figure 7: Scenario Discovery Expected Number of Deaths



(a) Trade-off coverage density summed damage



(b) Results of PRIM case 7 summed damage

Figure 8: Scenario Discovery Expected Annual Damage

4.3.1 Feature Scoring

From figure 9 below, there can be concluded that the total costs and the expected number of deaths depend the most on the dike failure probability in each of the locations. Furthermore, the figure shows that the total costs and the expected number of deaths in upstream locations are influenced more by the dike failure than the downstream locations. These conclusions are in line with the results obtained during the scenario discovery.

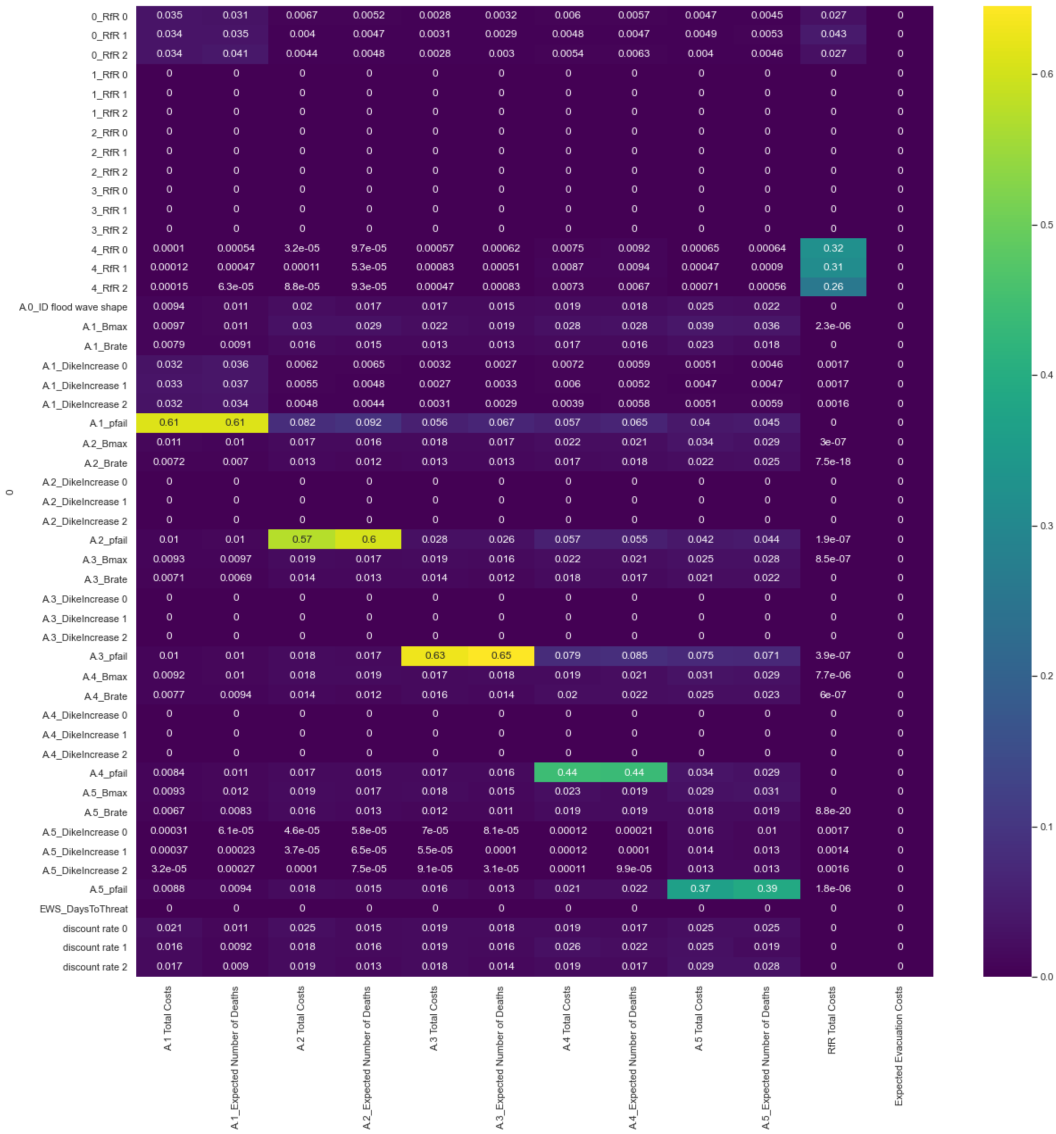


Figure 9: Feature Scoring

4.4 Directed search: MORDM

4.4.1 Stage 1 - Problem formulation

To increase the effectiveness in finding strategic solutions, it is mandatory to fully understand the multi-dimension problem at hand [29]. An abstract version of the process can increase comprehensiveness. In this chapter the problem is formulated using an XLRM model.

The XLRM framework is used to organize the problem and arrange discussions in deep uncertainty situations [23]. The problem is split up into four categories to structure relevant information. A model had two inward streams of information: external factors and policy levers. Then, within the model there are relationships, which create the outgoing information flow: performance metrics.

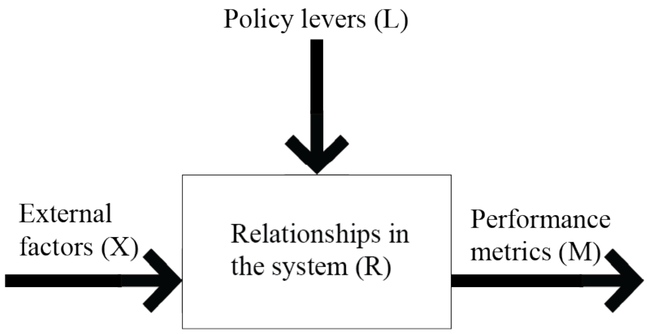


Figure 10: XLRM diagram

External factors (X)
External factors are exogenous uncertainties that play a role in the decision making process [23]. Decision makers do not have direct control over external factors, but have to take them into account as they can greatly affect the outcome. External factors are shown in table 1.

Table 1: External factors (X)

Uncertainty	Boundaries
Flood wave shape	140 possible wave shapes that describe discharge at upstream locations. How this wave shape is portrayed affect the estimated damage and possible danger
Probability dike failure	The hydraulic load a dike can handle. A higher number refers to a stronger dike (0-1)
Breach width final	Breach width can range between 30-350meters. The wider, the more water the floodplain can handle
Breach width model	The time in which the final breach width is reached, with the growth rate as uncertainty. (1, 1.5, 10) for 5,3,1 days respectively.
Discount rate	The value of expected future damage. A low value refers to high value of future damage. (1.5, 2.5, 3.5, 4.5

Policy levers (L)
Policy levers are policy measures that decision makers can take on which other actors base their strategies. Actors can set demands or boundaries on policy levers, and therefore influence the decision making process directly [23]. The dike height policy lever is aggregated over time and location, this leads to 3 time dependent levers over 5 different locations. Similarly, the Room for River lever is also aggregated over time and locations in the same way. Policy levers are shown in table 2.

Performance metrics (M)
Key performance indicators that stakeholders have chosen to rank the desirability of outcomes [23]. The performance metrics used for the multi-scenario MORDM are in line with those defined in problem formulation 3 of the dike model. The performance metrics are shown in table 3.

Relationships in the system (R)
Relationships in the system refer to the way in which uncertainties and levers are related to one another. These relationships influence the future and evolve over time [23], affecting performance metrics.

Table 2: Policy levers (L)

Levers	Boundaries
Dike height	between 0-10m of heightening
Room for River levers (river bed widening)	Five profiles of water level reductions can either be implemented or not (1 or 0). Based on other Room for river projects.
Time of warning before flood	0-4 days ahead

Table 3: Performance metrics (M)

Performance metrics	Description
Expected damage annually in Deventer	Economic damage due to expected flood damage in Euro's annually
Expected number of deaths in Deventer	Expected number of deaths in Deventer
Evacuation costs	Based on total number of people evacuating and number of days needing to evacuate, in Euro's
Costs room for river	Costs related to running the RfR project in Euro's

The last step before progressing to stage 2 is creating data. Firstly, a 0 policy scenario was constructed. This is a scenario in which all policy levers are set to 0, indicating that there is no change from the situation before the Room for River project. Subsequently, 10.000 scenarios were run with this policy and the Latin Hypercube sampling method. The results of this data generation are displayed in figure 11. The RfR Total Costs and Expected Evacuation Costs are both 0 in all scenarios because no Room for River policy is implemented because of the lack of policies.

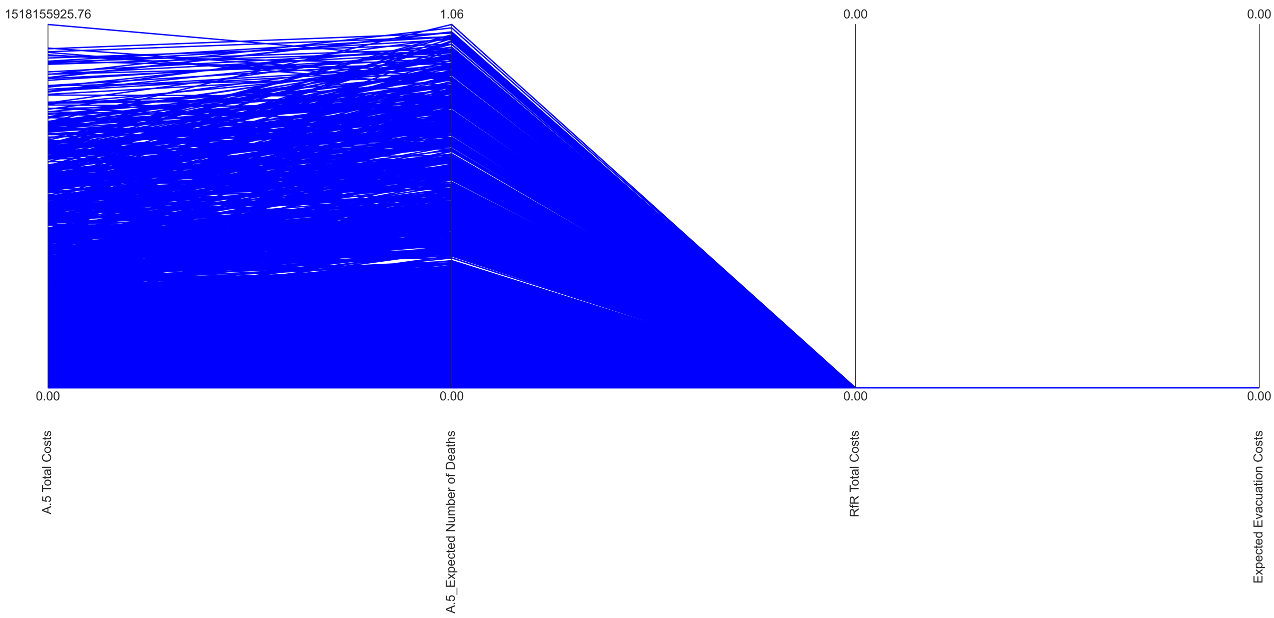


Figure 11: Data generation

From these 10.000 scenarios, the scenario with the highest expected number of deaths for Deventer and the scenario with the highest total costs for Deventer are used as reference scenarios in stage 2 of the MORDM. Additionally, the scenario with the lowest expected number of deaths and lowest total costs for Deventer is used as a third reference scenario, this scenario contained both of the lowest found values for the two performance metrics. The scenarios will be referred to as worst case casualties, worst case total costs and best case casualties & total costs, respectively.

4.4.2 Stage 2 - Generating alternatives

For each of the chosen reference scenarios in stage 1, an optimization will be run using the ϵ-NSGA2 MOEA. The ϵ-values used in this stage of the analysis are [100000,0.1,100000,1000] for the Expected damage annually in Deventer, Expected number of deaths in Deventer, Costs room for river and Evacuation costs respectively. Each optimisation was run for 35.000 nfe (Number of function evaluations). The ϵ convergence of each of these optimisations can be found in Appendix 7.4. As can be concluded from the figures in Appendix 7.4, the epsilon progress does not stabilise after 30.000 nfe. Therefore, it can be said that this model needs more function evaluations. However, due to a lack of computational power and time constraint given the time allocated to this research, this paper uses 30.000 nfe for the optimisation. More information on this lack of convergence can be found in the discussion in chapter 5.

The optimisation resulted in a 3 sets of Pareto optimal candidate solutions. 1731 candidate solutions for the worst case casualties, 2072 candidate solutions for the worst case total costs and 1919 candidate solutions for the best case casualties & total costs. These sets of candidate solutions were filtered based on a set of thresholds. The selected thresholds per set of candidate solutions, including the number of candidate solutions left after applying the thresholds, are presented in table 4.

Table 4: Thresholds scenario's

Outcome of Interest	**Threshold**
Worst case casualties	
Max death	0.01
Max total cost Deventer	80.000.000
Candidate solutions to be evaluated	26
Best case casualties & total costs	
Max death	0.01
Max total cost Deventer	1.000.000
Max total cost RfR	200.000.000
Candidate solutions to be evaluated	26
Worst case total costs	
Max death	0.01
Max total cost Deventer	80.000.000
Candidate solutions to be evaluated	21

Figures 12, 13 and 14 are parcoord (Parallel coordinate plots) figures that show the selected and disregarded candidate solution per reference scenario. The selected solutions are those that remained after applying the thresholds as presented in table 4. The figures do not only show how each solution scores on each policy, but also what trade-offs are being made.

In figures 12, 13 and 14, a general trade-off between the total costs and the expected deaths for Deventer can be seen. There are a few exceptions, but this is due to the fact that Deventer is strongly dependent on policy measures taken by upstream cities. Thus, in some scenarios Deventers' own investments don't lead to a decrease in the expected casualties. Moreover, a trade-off can be found between the expected deaths for Deventer and the RfR total costs. A lower amount of expected deaths leads to a higher RfR total cost and vice versa. Lastly, high RfR total costs lead to low evacuation costs and logically, low RfR total costs lead to high evacuation costs.

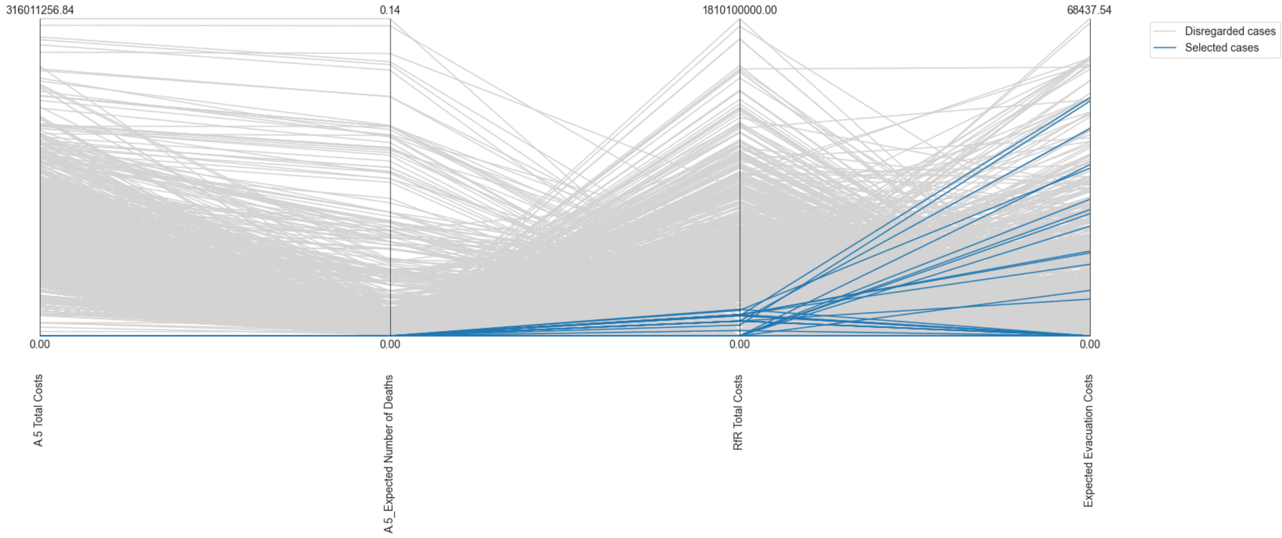


Figure 12: Parcoods best case casualties and costs

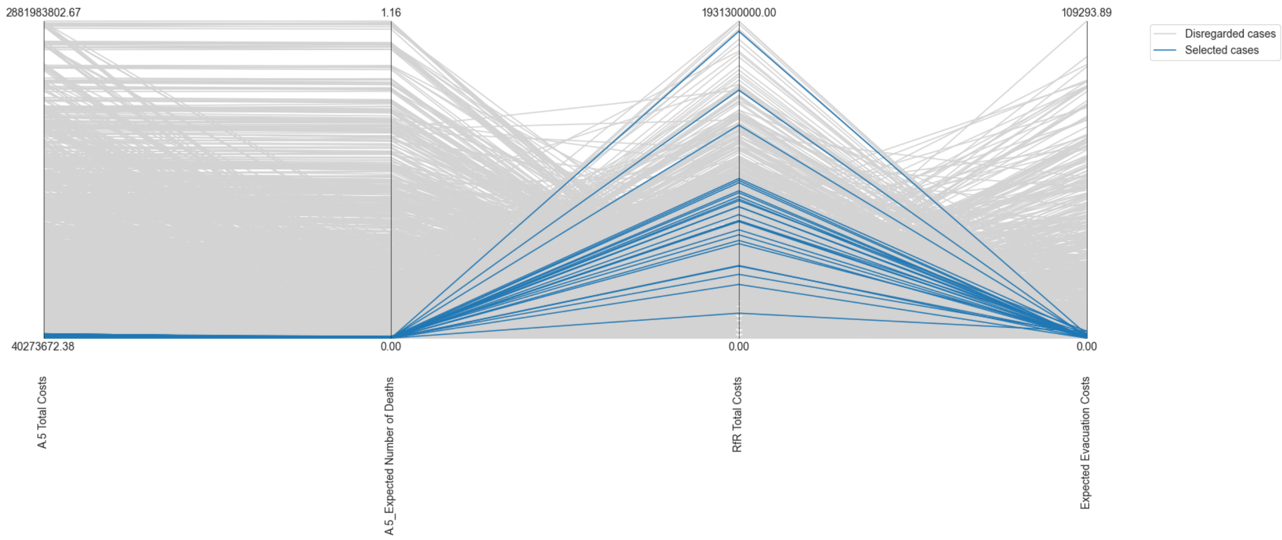


Figure 13: Parcoods worst case casualties

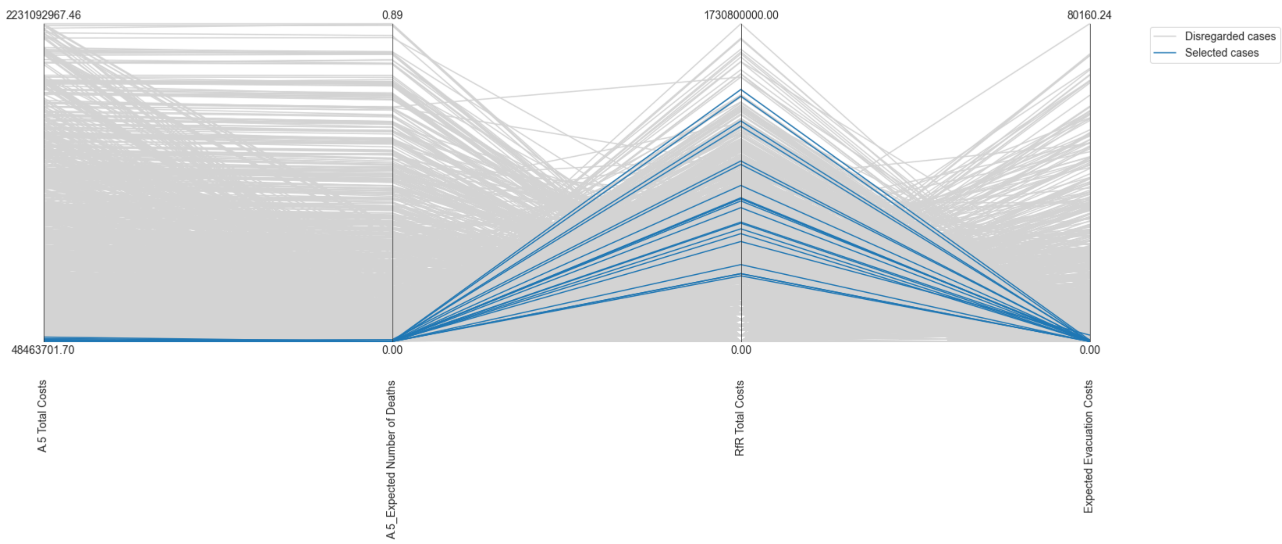


Figure 14: Parcoods worst case costs-wise

4.4.3 Stage 3 - Uncertainty Analysis

Now that a selection of candidate solutions has been made, all solutions are re-evaluated over uncertain factors to understand to what extend the solutions are robust against uncertainties. To do this, 1000 scenarios will be run per candidate solution. Subsequently, the robustness of each of the candidate solutions will be assessed using two different robustness metrics, the signal-to-noise ratio and the maximum regret.

Signal-to-noise ratio

The signal-to-noise ratio is calculated by taking the mean value of a variable in a data set and dividing it by the standard deviation of the same variable [22]. All 4 performance metrics have the same direction of desirability, lower values are desired over higher values. This implies that a smaller signal-to-noise ratio is preferred over a large signal-to-noise ratio. An ideal solution would score low on the signal-to-noise ratio for all of the performance metrics. Figures 15, 16 and 17 display parcoords of the signal-to-noise ratio scores for the worst-case casualties, best case casualties & total costs and worst case total costs candidate solution sets, respectively.

In figure 15, the 3 candidate solutions with lowest signal-to-noise ratio for the total costs for Deventer performance metric are highlighted in blue. The candidate solutions with the lowest signal-to-noise ratio for the expected number of deaths for Deventer are highlighted in green. In this case there seems to be a compromise solution. The candidate solution highlighted in green scores low on all 4 signal-to-noise ratios. This solution corresponds to policy 880.

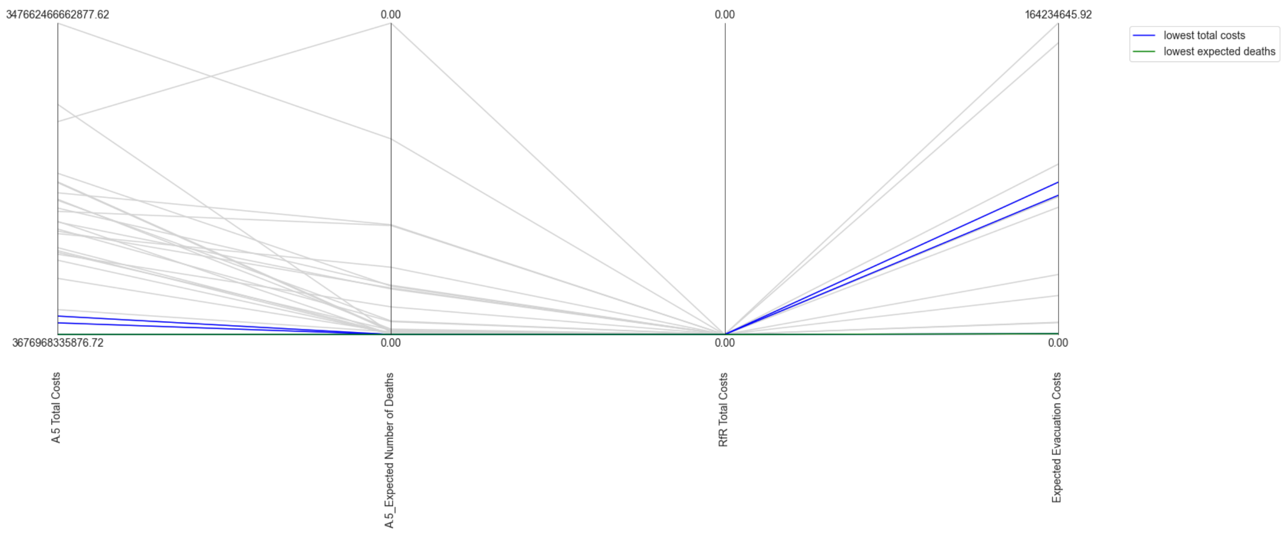


Figure 15: Signal-to-noise ratio worst case casualties

Figure 16 displays the 3 candidate solutions with the lowest total costs signal-to-noise ratio for Deventer in blue and the 3 candidate solutions with the lowest signal-to-noise ratio for the expected number of deaths for Deventer in green. Unlike the worst case casualties case, there is no single candidate solution that scores the lowest on all 4 signal-to-noise ratios. However, if purely focusing on the Deventer specific performance metrics, policy 1644 has the lowest, and thus the most desirable, signal-to-noise ratios.

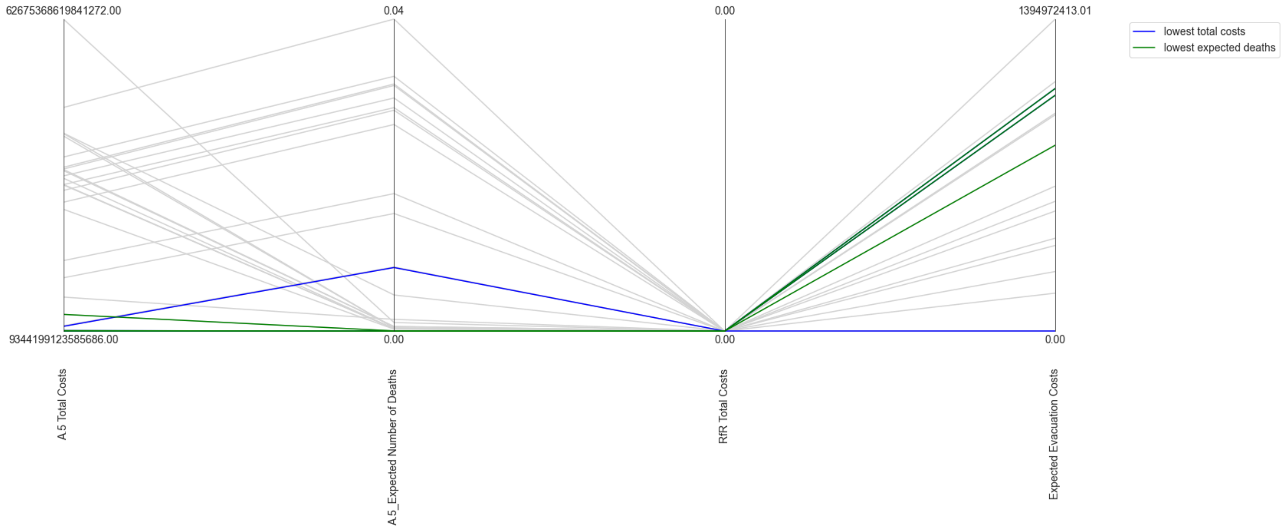


Figure 16: Signal-to-noise ratio best case casualties & total costs

Figure 17 displays the 3 candidate solutions with the lowest total costs signal-to-noise ratio for Deventer in blue and the 3 candidate solutions with the lowest signal-to-noise ratio for the expected number of deaths for Deventer in green. Similar to the results of the best case casualties & total costs, there is no one candidate solution that scores the lowest on the signal-to-noise ratio of all performance metrics. However, if purely focusing on the Deventer specific performance metrics again, there is one policy that clearly outperforms the other policies based on the signal-to-noise ratios, policy 496.

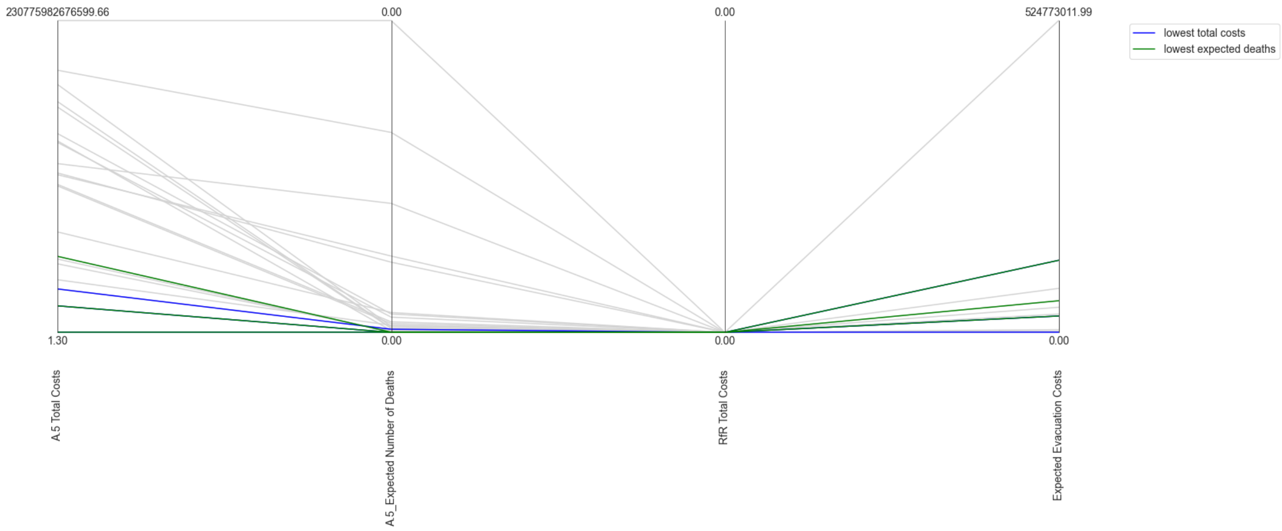


Figure 17: Signal-to-noise ratio worst case total costs

Maximum regret

The second robustness metric is the maximum regret. Regret is defined as the difference between a given policy and the best performing policy in a specific scenario. Maximum regret is the maximum regret value of a policy across all scenarios [22]. For all performance metrics, a low maximum regret value is desired. Figures 18, 19 and 20 display parcoords of the maximum regret.

For the worst case casualties candidate solution set, there is no single solution that provides the minimal amount of regret for each of the performance metrics, as becomes apparent from figure 18.

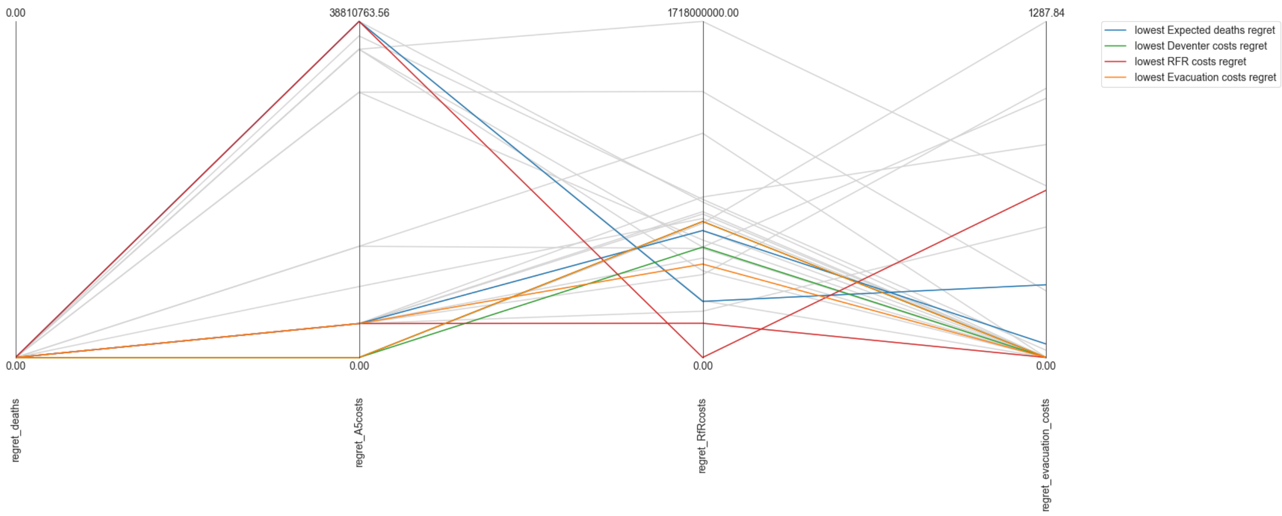


Figure 18: Maximum regret worst case casualties

The best case casualties & total costs set of candidate solutions provides a solution that scores the lowest on 3 of the 4 performance metrics, while also scoring relatively low on the maximum regret for the expected evacuation costs. This solution corresponds to policy 25.

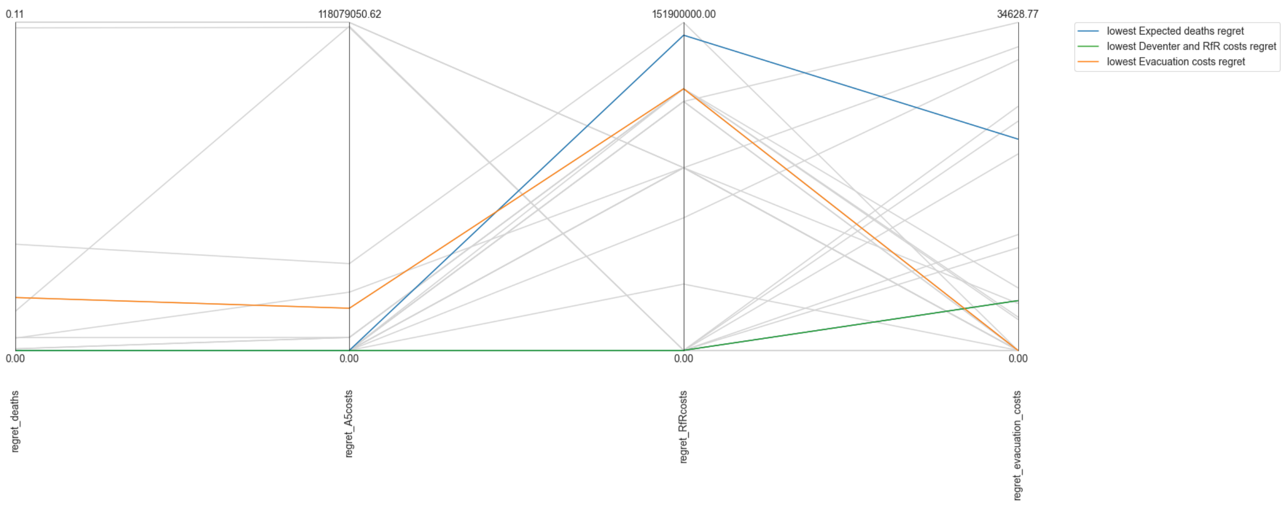


Figure 19: Maximum regret best case casualties & total costs

Similar to the outcomes in figure 18, the set of worst case total costs candidate solutions provides no clear solution that has the lowest maximum regret on all of the performance metrics.

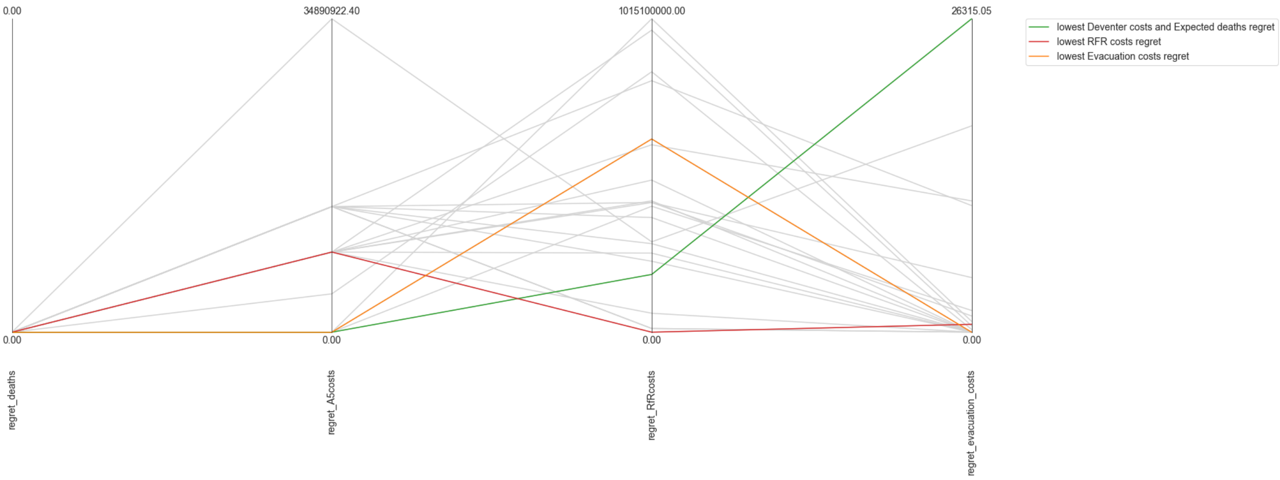
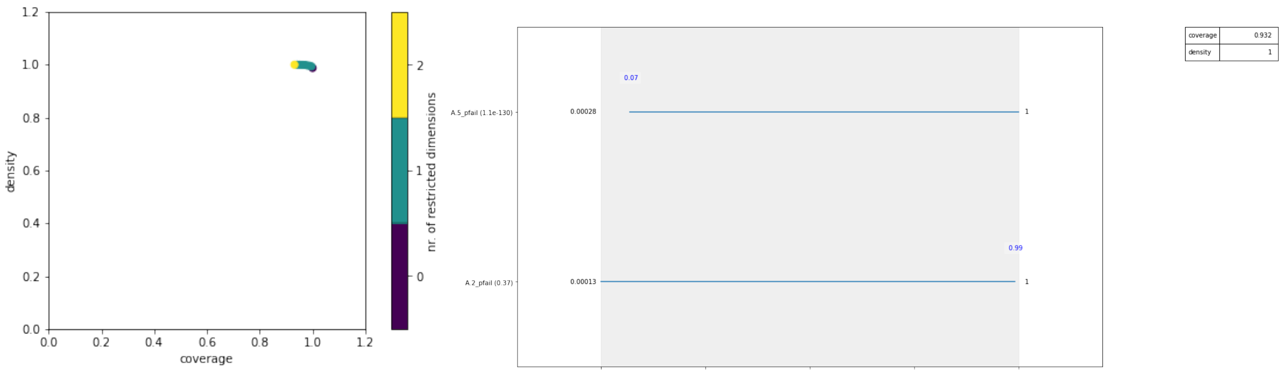


Figure 20: Maximum regret worst case total costs

4.4.4 Stage 4 - Scenario discovery

Similar to the scenario discovery in 4.3, the peel-alpha and minimum coverage threshold have been assigned values of 0.01 and 0.8 respectively, with an exception for the best case casualties & total costs. The minimum coverage threshold has been changed to 0.7 for this set, as the 0.8 value offered no solutions. The most important performance metric for the municipality of Deventer is the expected number of deaths, the threshold for which the outcome will be evaluated is $< 10^{-6}$, the same as in 4.4.4. When evaluating the results of the scenario discovery, (cases) boxes with a coverage of at least 0.8 were identified. The candidate cases were then compared and the case with the highest corresponding density was selected for further analysis. Figures 21a, 22a and 23a display the trade-off between coverage and density for the expected number of deaths cases. Figures 21b, 22b and 23b display the visual format of the selected case for each of the candidate solution sets.

The dike failure probability in Deventer and the dike probability in Cortenoever are the most vulnerable uncertainties regarding the expected number of deaths in Deventer.

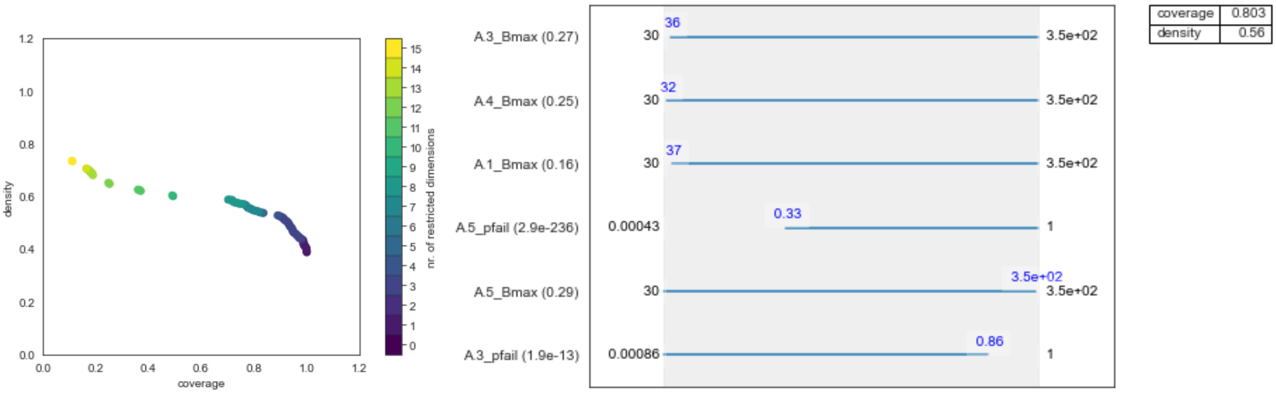


(a) Trade-off coverage density worst case casualties

(b) Results of PRIM case 8 A5_Expected Number of Deaths

Figure 21: PRIM Expected Number of Deaths worst case casualties

Where the selected case in the worst case casualties set of candidate solutions only contained 2 uncertainties, the selected case for the best case casualties & total costs is made up out of 7 dimensions. The vulnerable uncertainties for the expected number of deaths for Deventer are: The maximum breach width for Doesburg, Zuthpen, Gorssel and Deventer, and the dike failure probability for Zuthpen and Deventer.

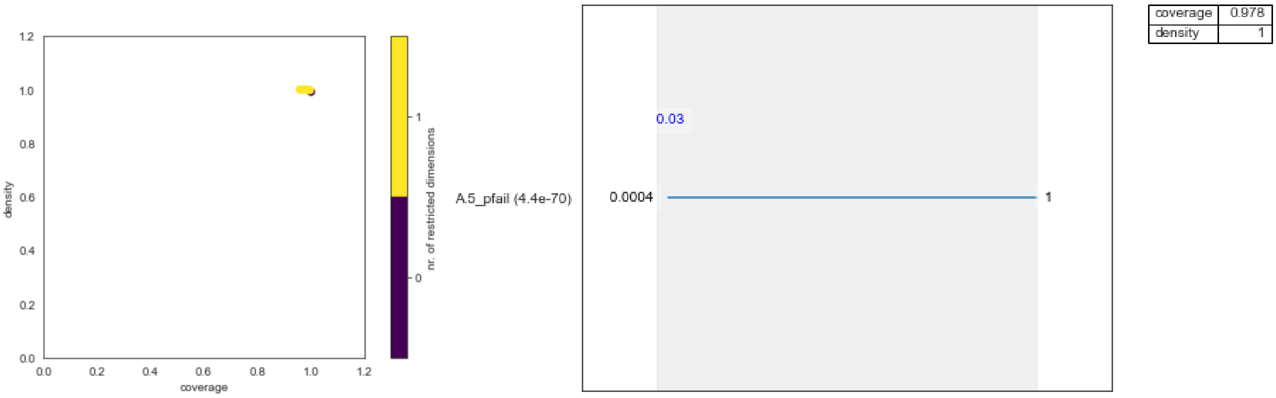


(a) Trade-off coverage density best case casualties & total costs

(b) Results of PRIM case 55 A5_Expected Number of Deaths

Figure 22: PRIM Expected Number of Deaths best case casualties & total costs

The selected case for the worst case total cost set of candidate solutions contains only 1 dimension. The dike failure probability in Deventer is the most vulnerable uncertainty regarding the expected number of deaths.



(a) Trade-off coverage density worst total costs

(b) Results of PRIM case 3 A5_Expected Number of Deaths

Figure 23: PRIM Expected Number of Deaths worst case total costs

4.4.5 Results

Based on the results from the multi-scenario MORDM, a few policies have come forward that are robust and offer the desired effects on the performance metrics that are of interest to the municipality of Deventer. Per reference scenario, one policy will be highlighted, these policies are the following: Policy 1895 for the worst case casualties reference scenario, policy 488 for the best case casualties & total costs reference scenario and policy 1795 for the worst case total costs reference scenario. These three policies are both robust in terms of maximum regret and signal-to-noise ratio, while also scoring low on the two Deventer specific performance metrics, the total cost for Deventer and the expected number of deaths for Deventer. An overview of the results of the policies on the performance metrics can be found in table 5.

Table 5: Selected policies

Policy	Expected number of deaths for Deventer (Annual)	Total costs for Deventer (Million €/year)	RfR total costs (Million €)	Expected evacuation costs (Million €/year)
Worst case casualties				
895	0.000029	40.5	837.5	9.7
Best case casualties & total costs				
488	0.0082	75.84	121.2	0.0028
Worst case total costs				
1795	0.000005	53.17	964.8	0.0065

Policy 895
Based on the worst case casualties scenario, policy 895 was selected. This policy consists of heightening the dikes in all 5 locations, widening the river in Cortenoever, Gorssel and Deventer and implementing an early warning system of 3 days.

Table 6: Policy 895 RfR

Phase	RfR Cortenoever	RfR Gorssel	RfR Deventer
1		Yes	
2		Yes	Yes
3	Yes	Yes	

Table 7: Policy 895 Dike heightening

Phase	Dike heightening Doesburg (dm)	Dike heightening Cortenoever (dm)	Dike heightening Zutphen (dm)	Dike heightening Gorssel (dm)	Dike heightening Deventer (dm)
1	4	1	1	0	6
2	0	3	0	0	0
3	2	7	6	7	0

Policy 488
Based on the best case casualties & total costs scenario, policy 488 was selected. This policy consists of heightening the dikes in all locations, except for Deventer. Widening of the river only occurs at phase 3 in Gorssel, and the policy contains an early warning system of 3 days.

Table 8: Policy 488 Dike heightening

Phase	Dike heightening Doesburg (dm)	Dike heightening Cortenoever (dm)	Dike heightening Zutphen (dm)	Dike heightening Gorssel (dm)	Dike heightening Deventer (dm)
1	3	3	0	1	0
2	0	1	1	0	0
3	1	0	0	4	0

Policy 1795
Based on the worst case total costs scenario, policy 1795 was selected. This policy consists of heightening the dikes in all locations, widening the river at all locations except for Doesburg and the policy contains an early warning system of 3 days.

Table 9: Policy 1795 RfR

Phase	RfR Cortenoever	RfR Zutphen	RfR Gorssel	RfR Deventer
1		Yes	Yes	
2	Yes			Yes
3	Yes		Yes	

Table 10: Policy 1795 Dike heightening

Phase	Dike heightening Doesburg (dm)	Dike heightening Cortenoever (dm)	Dike heightening Zutphen (dm)	Dike heightening Gorssel (dm)	Dike heightening Deventer (dm)
1	0	0	7	2	9
2	0	2	7	0	0
3	1	0	0	3	0

5 Discussion

In this section the key limitations of all analyses performed will be discussed, both from a methodological and policy arena point of view. The possible impact of the limitations on the conclusions will be explained and recommendations for future research will be given.

First of all, the uncertainties that are taken into account during all the analysis are adopted straight from the case description and the simulation model that was given. No effort was made to investigate the pulished literature to ascertain if important missing uncertainties were missing. The reason behind this is that due to the time scheduled for this course and the results expected, it was not deemed necessary to add more uncertainties. However, not including important uncertainties could lead to adverse consequences for people, countries, and the earth [37]. Furthermore, ignoring those uncertainties can lead to poor policies. A future improvement could be to critically assess whether important uncertainties are missing, and if so, adding them to the simulation model. In the following paragraphs, analyses specific limitations will be discussed.

A significant limitation of the Open Exploration must be pointed out. According to Moallemi et al. (2020), "current exploratory modelling approaches do not provide much guidance for how their outputs should be interpreted". This limitation is named "limitations in communication and interpretation of the results". This limitation can also be seen back in the visualization of the results of Open Exploration. Due to the limited cognitive capacity of the authors and the readers of this report, understanding the visualizations of Open Exploration can be a challenge. Recognizing patterns and comparing results between different locations is quite difficult. As result of this limitation, it could be possible that conclusions can be drawn errant, or that relationships or patterns are overlooked. Furthermore, in this report there is mainly looked at uncertainties in input variables. However, as stated by Moallemi et al. (2020), it is also important to look at other forms of uncertainties such as variation in model structural relationships and equations. Recommendations for further research are therefore, 1) Verify conclusions by using techniques for viewing highly multi-dimensional data [28] and 2) investigate multiple forms of uncertainties.

Secondly, Global Sensitivity Analysis computational constraints limited the analysis that could be undertaken. As such in the analysis, only the Sobol method was utilized in the sensitivity analysis. Other methods could not be explored and compared as a result. Provision of dedicated virtual machines could enhance the analysis that could be undertaken in future iterations of course. However, it is deduced from the sensitivity analysis carried out that the breach and probability of failure of the dikes are the main forerunners locally as well as regionally jeopardize the priorities or objectives of the municipality.

Scenario Discovery also comes with some limitations. One big limitation that was faced during Scenario Discovery is the lack of validated thresholds. Those thresholds determine which cases are included in the analyses and which should be left out. It was known that the problem owner, Deventer, aimed to keep the expected number of deaths low and that they cared less about costs. However, it was not clear what they mean by 'keeping the expected number of deaths low' and 'caring less about costs'. There were no clear thresholds, and therefore assumptions were made. In future research, it would be better if the problem owner was contacted once more to either ask what thresholds they want or to ask if they agree with the thresholds that are set. Currently, both is not done. Also, the scenario's that are discovered are combinations of a few factors. However, according to Bryant and Lempert(2010), there are also many social, cultural, political and organizational factors that are important when making a decision. These factors are difficult to quantify, and therefore they are not taken into account in the simulation model. As a result, information coming from such models can be biased. A way to overcome this problem is combining the model outcomes with expert opinions [3].

The last limitations that will be discussed are those of MORDM. As with the Scenario Discovery, thresholds had to be set in order to execute MORDM. Thresholds were chosen for the maximum expected number of deaths and the total costs for Deventer. However, as with Scenario Discovery, those thresholds are assumptions based on the one conversation that took place with Deventer. Those thresholds are not validated by Deventer, and therefore it is uncertain if those thresholds can be seen as valid. A future recommendation would be to pass the thresholds along Deventer to find out whether the problem owner agrees with the chosen thresholds or not. Furthermore, the model was run with multiple number of function evaluations (nfe's). The model was run with a nfe up to 50.000, but the epsilon kept progressing and the model did not converge. Running the model with a nfe of 50.000 took the computers in use about 12 hours. Due to the time scheduled for this course and the need to continue with the remainder of the assignment, there is decided to continue with the results obtained from the nfe of 50.000. As a result, there is no guarantee that all optimal solutions have been found by the algorithm [22]. A recommendation for further research is to run the model with a higher number of nfe's and preferably on a more power full computer.

As for the policy arena, some limitations have to be taken into account. During the process there has been no contact with other cities about their main interests and preferences for the risk management plan. Because of this, we have made certain assumption about what was reasonable for their cities in number of deaths and damage for example. To improve this process it would be better to negotiate more with the other parties involved to get a clearer picture of the whole situation and figure out what they want and how they want to reach it. By this, we could take their point more into consideration during our search for policy options. During the debate for the risk management plan this will probably lead to better understanding conversations and hopefully more consensus in the end.

6 Conclusions

This research has been carried out to give the municipality of Deventer advise about the 'Room for River' project. This project will develop a flood risk management plan for the upper branch of the IJssel River in the Netherlands. This, to make sure that not only the chance of flooding will reduce, but also the damage will be limited.

Deventer is one of the big cities alongside the IJssel River which will be extremely harmed in case of a flood. For this reason, is important to establish an adequate risk management plan in which all stakeholders are considered. Multiple analysis have been performed to evaluate the situation and give policy advice about stakeholders' risks and chances concerning different solution options. Deventer, considers the number of deaths the most important criteria, they stated casualties should be avoided at all time. However, the difficulty in designing the risk management plan is that all other actor involved have all different goals and interests.

First, an Open Exploratory has been conducted to look at the model behavior and identify the bandwidth outcomes. There can be concluded that Deventer, compared to the other cities, has a high vulnerability when the Ijssel were to flood. Another notable conclusion is the fact that Deventer could better invest in dikes than in the Room for River costs, since dikes will result in less damage.

After that, a Global Sensitivity Analysis has been conducted to determine how the various factor interact and influence the different outcomes and how these should be taken into account for further decision making relevant to the problem owner. It is a prerequisite to fully understand how interconnected the problem is and how implemented policies in isolation may run in contrast to the goals and priorities of the problem owner identified in this report. The GSA showed that Deventer's flood risk management requires actions that are multi-pronged and run in tandem with other flood risk projects/programs by neighbouring municipalities in order to attain its overarching goals. Investment in dikes as well as in RfR is paramount. Dialogue and negotiations with relevant stakeholder also play an integral part of this process.

From the scenario analysis, it is evident that the key parameter that runs contrary to the priorities of the municipality is the physical defence systems in place. Failure of dikes has been observed to cause the most casualties and damage cost. As such, for Deventer it is most important that the dikes in Deventer are reinforced to limit the number of deaths and damage in the city. Deventer is also dependent on the strength of the dikes of the other cities, but this impact pales in significance in comparison to that of municipality's. Altogether, strengthening the dikes is necessary with safety and cost considerations in focus. This was also evident in the Feature Scoring analysis.

Insights from the directed search give indication to policies that could be undertaken in the minimization of casualties and costs that could arise from an outcome of flooding. Although investments in room for river are significantly high, it has the lowest number of casualties. As such, the municipality deems to benefit from participation in the Room for River program. However, it is of great importance that the other cities in the Room for River program participate as well. The multi-scenario MORDM showed that all best performing and most robust policies for Deventer involve at least as much, if not more action from the other cities. This is due to Deventer's downstream location, which therefore feels the effects of other mulicipalities' policies. The Room for River program combined with the traditional strengthening of dikes in all 5 cities is considered to be the best strategy the municipality could pursue in achieving its intended goals, along with a early warning system of 3 days. As was made apparent from the MORDM, the most important place to realise the Room for River project is in Gorssel.

Based on all analyses which were conducted by the analysts of Deventer, an advice is formed which would best fit Deventer. In this advice, focus is put on minimizing casualties and maintaining its historic city centre. However, as Deventer is a relatively small stakeholder in this project, it was important to consider the outcomes for other parties as well, as a solution which would only benefit Deventer is unrealistic. Therefore, **we advice Deventer to strive for dike hightening in all cities, and have Gorssel make Room for the River against a fair compensation. It will also be adviced to set early warning systems of 3 days.** In our advice, we strive to present a solution which will hold over time, and be sufficient for a number of years. As could be seen in the 4, depending on the refernce case, slight alternations in the preferred policy advice can be made, which is important for Deventer to keep into account. The current policy advice seemed most realistic and achievable.

Finally, it must be emphasised that the municipality of Deventer is not isolated in achieving its goals solely through the policy decisions it pursues. As physical defence mechanisms of other municipalities located along the IJssel exert indirectly an influence on casualties, damage and associated costs in the event of a flood. The municipality must monitor policy decisions taken by other municipalities and seek to influence these policies that run contrary to its priorities. Dialogue and negotiations with identified stakeholder are instrumental in this regard. Although considerations and information on budgetary constraints were not included in the analysis of the problem, further choice analysis could be undertaken to quantify the cost per investment unit per avoided casualty and threshold limits/trade off considerations that could be tolerated in the event of a major flood occurrence if the municipalities budgets are constrained.

7 Political reflection

This chapter reflects on the political game for the Room for the River project for the Ijssel. First, a short introduction is given and the main goals of the Municipality of Deventer are presented. Next, a brief description is given on the role of analysts as seen by the writers of this report. Part 7.2 of this reflection presents the different tensions and challenges found for Deventer within the political arena during the debate. These challenges are briefly presented, followed by an evaluation on how these tensions are encountered during the project and how this approach could have been better. Finally, this chapter ends with a concise reflection on the presented strategies.

7.1 Introduction

The reflection has been written from a perspective of analysts who gave advice to the Municipality of Deventer. The main goal of this advice is to inform the Municipality on the Room for the River project to prepare them for the political game. Within chapter 2 of this report, a broad introduction to the case is already given, including a brief outline of the political arena. It is therefore not necessary to introduce the case again in this chapter. Before going into the different tensions and challenges a clear description of Deventers' goals for the Room for the River project is needed.

Deventer has one main argument and substantiates this with multiple sub-arguments. They state that their main objective is to preserve the safety of its citizens, and additionally, want to minimize the damage of the historical city centre during floodings. Deventer believes their city is more prone to harm (both human and material) than rural areas because of two reasons. Firstly, the city has as a higher population density than rural areas which would lead to a greater number of inhabitants and houses being harmed. Secondly, they mention that the city centre has historic value which could be badly harmed. It can be assumed that the Municipality of Deventer also has some standard goals while playing the political game just like every other stakeholder. For example, they do not want to take unreasonable amounts of economic or land losses, take unreasonable amounts of risks or strongly lose political power.

As explained by professors of this course, in this project analysts do not have a political agenda. Their main interest is to conduct a good analysis which serves their employer (Deventer) well in the political decision-making process. Getting paid, having happy customers and maintaining a good reputation are analysts' main goals. Analysts can set their own boundaries when they are sucked into a more political game by their employers.

7.2 Tensions and challenges

First of all, it has to be stressed that the steps that were taken by us as analyst for Deventer did not lead to comprehensive advice for Deventer on what exact policy to strive for before starting the final debate. This is the result of multiple challenges that were encountered during the decision-making process. Within this part, four different tensions and challenges within the political arena are presented. These tensions are experiences from an analyst viewpoint while working for the Municipality of Deventer, which has a certain "watching from the sideline" perspective. This situation is visualized in Figure 24, which shows the actor field for the Room for the River project on the Ijssel. It is important to emphasis that the analyst perspective is as far away from the actual policy making as possible.

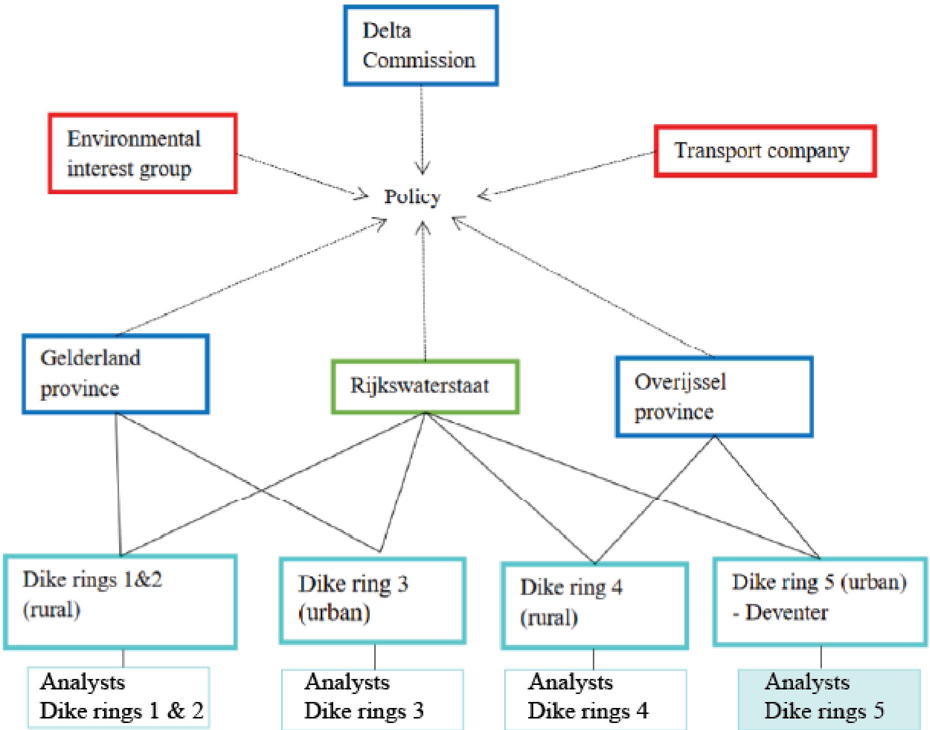


Figure 24: Political arena [17]

7.2.1 Low hierarchy within political arena

The first challenge for the Municipality of Deventer is that within the bigger decision-making process they are being represented by the province of Overijssel. This means that Deventer only has the opportunity to express their interests in a small pre-debate with Gorssel and Overijssel. Whereas Overijssel was included in a bigger debate with the province of Gelderland, Rijkswaterstaat and other stakeholders, this can be seen in Figure 24. Almost every stakeholder in this debate, especially Gelderland and Overijssel, have different, sometimes contradictory, goals they strive for. All together, this places Deventer low in hierarchy in the political arena, which makes them heavily dependent on other parties. When translating this situation to the impact of given advice, it is conceivable that important information or specific emphasized facts are lost in the other debate rounds and handovers of goals, wishes, interests and agreements between stakeholder relations like Analyst-Deventer, Deventer-Overijssel and Overijssel-Rijkswaterstaat.

What has been done?
To minimize this challenge during the process, the analysts have attempted to converse with other analysts about the interests of other stakeholders, unfortunately with no success. Throughout the decision-making process, it has felt as if the analysts of Deventer have been left in the dark. This, however, is not surprising considering Deventer's position in the hierarchy. The absence of such information restricts analysts in giving adequate advice, which will also suit other stakeholders. This is important, as Deventer is a 'small' stakeholder, and will most likely need to come up with solutions that other parties will support. They do not have the strength to push through solutions that only benefit them. The fact that the information flow in politically related decision-making processes is often restricted and information is kept private between actors, leads to uninformed decisions [12]. Therefore, a major part of the things that were said during the debates, were new to the analysts. If this information would have been known sooner, solutions that were preferred by Deventer could have been evaluated better to fit interests of other stakeholders.

What can be done?
In the future, it could be of great use to the analysts to have a broader understanding of the stakeholders and

their interests in a decision-making process. This could have been done through more communication between analysts, or through Deventer acquiring more knowledge on other stakeholders and sharing this with their analysts.

7.2.2 Overijssel representing Deventer and Gorssel

Secondly, in addition to (but also emphasized within) the earlier mentioned challenge, Overijssel represents the other Municipality, Gorssel, at the same time in the same policy-making process. Because Deventer and Gorssel have opposing interests to a certain level, this could potentially lead to tensions and challenges for Overijssel. Overijssel needs to be clear and concise when acting in the debate with Gelderland, Rijkswaterstaat and other stakeholders. If they want to accomplish the maximum they potentially could, they need to have one clear story with a proposal that sharply aligns and does not contradicts itself, for which agreement must exist between Gorssel and Deventer.

What has been done?
An important aspect in resolving this tension was the first debate with Overijssel, Gorssel and Deventer. During the debate, everyone presented their goals and vision on the situation and worked together by listening to each other and understanding the opponents point of view. Parties spoke about joined strategies to have the most impact within the bigger debate and even mentioned terms like "us" against "them". Importantly, Deventer explained why they did not want heightening of dikes, which was substantiated with model outcomes. In their opinion, the danger needed to be solved upstream so that downstream areas, where impact would be bigger, are be protected. Based on model outcomes, Gorssel was willing to cooperate and accept floodplains within their dike ring if their farmers were compensated with comparable amounts of land. This compromise was labeled as the "first game plan" which could be played by Overijssel in the large debate. In the final debate, Overijssel presented this option and formed a strong solid bond. Rijkswaterstaat went along with their line of reasoning and searched for a solution in the upstream region of Gelderland while making use of the possibility to create floodplains in Gorssel.

What can be done?
Apart from the fact that the used strategy worked well, there is always room for improvement. Model outcomes were extensively used within the debate and line of reasoning for their own regions, but these also could have been produced for opponents. When the situation of opponents would have been further investigated, this could have been used within the final debate and could have lead to more benefits for Overijssel and its Municipalities.

7.2.3 Upstream vs. downstream

This third challenge regards Deventer's location; Deventer is located downstream, and believes that the consequences for all stakeholders will be limited if policy measures are taken in the upstream area. However, as only Deventer, Overijssel and Gorssel were present in the first debate, no stakeholders in the upstream areas were there to give feedback on this motion. Meaning, the dike rings affected by this suggested policy by Deventer, were not able to defend themselves. Therefore, the first debate was easily concluded: the upstream areas would have to make room for the river. Therefore, in the second debate, it came to a surprise that the upstream areas were not agreeing with the presented policy. They wanted more compensation and give less land to make room for the river. This is in line with Simon Vydra's (2022) prediction where it is stated that 'losers' will challenge and disagree with policies that create a disadvantage for them. Deventer had stated (in the first debate) they were willing to pay upstream areas to make room for the river, as it would benefit Deventer. However, as Deventer only heard about the complaints of the upstream areas in the second debate, and Deventer was not able to 'speak for themselves', Deventer was not able to let upstream areas know about their willingness to give compensation.

What has been done?
To put Overijssel, Deventer and Gorssel all on the same page, a debate about possible outcomes was scheduled. However, as Overijsel represents Deventer and Gorssel, it was easy to agree to their wishes. Meaning, Overijssel concluded measures should be taken the upstream areas as that would benefit upstream and downstream areas simultaneously. While these debates were already scheduled by the course, no action was taken to also organize a debate with the different dike rings together of both up- and downstream areas. The effect of having no conversation between the multiple dike rings lead to Deventer being unable to come with good compromises as

interests were unknown.

What can be done?
To solve the problem of important stakeholders missing information on the wishes of other stakeholders, an informal meeting could have been organized. In this meeting, all dike rings would be able to meet and explain their wishes. In accordance to the game rule 'a loser acquires a right' [7], Deventer would have been able to explain to other dike rings that they were prepared to give compensation. This would have lead to a better understanding between the dike rings and less rebuttal from the 'loser'. For the analysts, it would have been useful to know important outcomes for other dike rings, as the analyses could have been done to predict whether solutions would suit other dike rings. This would make Deventer (and Overijssel) more prepared in the debate.

7.2.4 Knowledge gap between analysts and Deventer

Lastly, throughout the entire project is has become increasingly clear that Deventer was unaware of the capabilities an analysts has and vice versa. Deventer seemed to be hesitant to ask questions to the analysts, and therefore missed the opportunity to gain information on the project and other stakeholders. This, for example, became apparent in the first debate, when Deventer was striving for dike heightening. Upon which Overijssel mentioned the view they would lose by building such a high dike. Clearly, this part of the problem was overlooked and not accounted for. However, as the analysts were not asked to look at anything but casualties and expenses, the analysts were unaware the dike heightening could have other negative aspects. If this would have been done differently, Deventer could have been more prepared for the debate. If this motion had been discussed with the analysts, the analysts could have asked questions. However, there was no opportunity for analysts to ask such questions.

What has been done?
This tension became apparent later on in the process, so no specific actions were undertaken on beforehand. Also, the way in which Deventer have approached their analysts have lead to the analysts taking on an prescriptive approach [38] . This means that Deventer has outlined the problem at hand, and solutions are sought to fit their problem formulation. The solutions that are discovered are focused on Deventer's outcomes of interest (ooi): minimizing casualties and minimizing costs. The ooi's are also checked for Gorssel (another municipality which is represented by Overijssel), see 7.4. The analysts are only asked to do search for specific information, which gives Deventer limited knowledge. This is an example of how feasible decisions can be overlooked due to political blindness towards one's own personal interests [10].

What can be done?
Upon reflection, Deventer could have taken another approach regarding the style of decision aiding towards the analysts: a constructive approach. In this approach, more time is spent on accurately formulating the problem at hand [38]. Deventer has been informed by Overijssel and RfR-project on what the situation is, but have not carefully analysed what the problem exactly means for them and other municipalities. Together, Deventer and the analysts could have explored more solutions and discovered stronger arguments to fit their wishes. If this would have been done differently, Deventer could have been more prepared for the debate. If Deventer would have come up with a stronger problem formulation from their point of view, their solutions could have been more convincing.

7.3 Reflection

Communication
When reflecting on the strategy to have the desired impact of the analysts, the first thing that needs to be mentioned is the fact that very little advice has actually been given. On one hand this had to do with the fact that there was limited communication between Deventer and the analysts. Within the first weeks, both project groups found each other and exchanged some insights, but minimal. After a few weeks, contact was made again and Deventer asked for how selected policies affected Deventer cost-wise and casualty-wise, see 7.4. The type of advice that was sought, lead to a prescriptive advice style which carries certain limitations. When looking back, advising more in a constructive manner would bring more opportunities with it as well as leading to advice in a broader spectrum. Where prescriptive is focused on solving specific problems, constructive is more in-depth and focuses formulating the problem to fit the employer and use that as a starting point for finding solutions [38]. This will lead to a better and broader understanding of the situation and creates a situation where analysts can come up with 'out of the box' solutions for the client which can be helpful.

Course organisation
The second important note for the reflection is the fact that there was no finished, complete policy advice ready before the first debates started. This partly has to do with the fact that the period of the course is only 10 weeks and, understandably, everything needs to be planned within this tight schedule. This resulted in a situation where most of the analyses were only partly done and the analysts just started to get a grip on what the model results actually meant. Nevertheless, explaining these results to the client is another step further and thus it sometimes felt that we were also not yet ready to give proper advice. In combination with this first point, at some points we did not exactly know what was expected from us as analysts to provide to the client. "Giving policy advice" is a broad term and especially with Deventer also not exactly knowing what to ask us, we struggled to present Deventer with new innovative data.

Inexperience with debate format
The last important notion continues where the previous point stopped: inexperience. For the analysts it was not the first time that policy advice needed to be given, but never in this format. Simultaneously, we noticed that Deventer was hesitant to ask us for information, as they were also running their own models and generating data. An overview of points of improvement for the analysts is given underneath.

- During the debates it became clear that argumentation with model outcomes, confrontation with and convincing of stakeholders like Overijssel can lead to real changes of vision and play of the game. This can be accomplished by using the model to explore weaknesses of opponents and possibilities to bring to the table to pass certain risks to opponents.
- Another important lesson is that the model can also be used to search for shared goals with allies in order to convince them to work together and form a bond. When looking for interests of allies, this gives a sign of willingness to cooperate which gives more political power.
- The last lesson learned is the fact that ways of communication and framing lead to different interpretation of results. Which in turn, could lead to increasing the influence analysts can have by for example using different measures, different figure layouts and even different presentations of results based on used words and approaches to gain more trust and allies.

7.4 Proposed strategy

From here on, advice will be given on what strategy could be adopted in the future that tackles the challenges that were encountered. The goal of this strategy is to come up with advice that can contribute to real-world decision-making.

In hindsight, in the future we would suggest a strategy that emphasizes on communication between the multiple stakeholders. Once the interests of other stakeholders are known, possible solution outcomes can be tested for those stakeholders, and a predictions can be made as to whether they will accept such a solution outcome. When being aware of one's opponent's values and preferences, these can be used to negotiate and come to a compromise [6]. Opponents' values can be adapted, to serve a common goal. Or opponents' values can be boycotted, playing in on their downside effects. For example, in the case where the upstream areas did not want to make room for the river, the downside effects of such policies can be shown, and all the negative consequences for downstream areas can be emphasised to persuade them into compromise. Thus, a future strategy would be to force communication between (smaller) stakeholders, so that coalitions can be made and negotiations can start [7].

However, it must also be noted that this proposed strategy brings some risks into the political game. The first main risk is that when adopting the opponents' values in order to reach a negotation or compromise, one must be careful to step into another stakeholder's frame [6]. When using the opponent's words, it must be made sure that the same language is spoken. Meaning, all parties must be clear on definitions, goals and interests. The second risk is that when playing open cards about your interests, stakeholders may get to know your 'weak points'. Knowing what goals stakeholders find most important to preserve, it most likely means they are willing to let other things go. Therefore, when being open about your preferred solutions, it can be that your openness is misused in the negotiating process. Therefore, understanding other stakeholders' opinions would have been useful during this project. As analysts do not have a political agenda and Deventer is not a main stakeholder, knowing the preferred solutions of other parties would have helped in giving Deventer objective realistic advice.

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Appendices

Appendix A: Main Interests and objectives of stakeholders

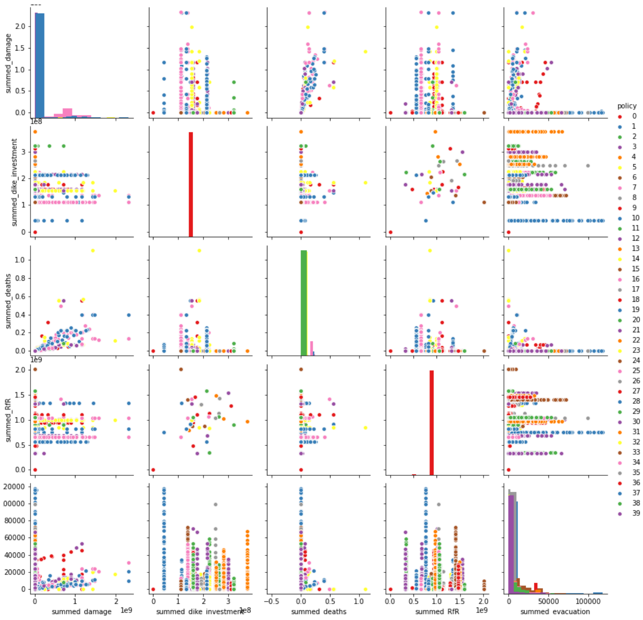
To trace the main interests and objectives of the stakeholders each one of them is interviewed in combination with secondary research.

Stakeholder	**Interest**	**Objective**
Rijkswaterstaat	Manage the progress of the project as an organ of Ministry of Infrastructure and Water Management.	Assure a smooth progress and protect the quality of the project. Facilitate if necessary using local knowledge and community relationships [31].
Delta Commission	Increase water safety in river regions.	Building a bridge between policy and implementation while Increase river discharge capacity in consultation with locals [11].
Transport Companies	Continue shipping along the Ijssel with minimal delay.	Lobby for the Ijssel being at least 4meters deep and as wide as possible to optimize transport.
Environmental Interest groups	An environment which allows for a (bio)diverse combination of animals and nature.	Protecting the biodiversity of and along the Ijssel, while maintaining high water quality.
Province of Gelderland	Protecting citizens from the Ijssel while preserving agricultural and economic activities.	Setting adequate interests that satisfy the interests of dike ring 1, 2 and 3.
Province of Overijssel	Protecting citizens from the Ijssel while preserving agricultural and economic activities.	Setting adequate interests that satisfy the interests of dike ring 4 and 5.
Dike ring 1 & 2 - Doesburg & Cortenoever(Rural)	Doesburg and Cortenoever are rural areas with ca. 11.000 and 250 inhabitants, respectively, along the Ijssel.	Protecting citizens from flooding while being able to host agricultural activities all year around.
Dike ring 3 - Zutphen (urban)	Zutphen is an urban city with ca. 40.000 inhabitants, along the Ijssel.	create policies which allows for urban recreation and prevent flooding.
Dike ring 4 - Gorssel (rural)	Gorssel is a rural area with ca. 4.000 inhabitants along the Ijssel.	Protecting citizens from flooding while being able to host agricultural activities all year around, and simultaneously protecting the natura-2000 area.
Dike ring 5 - Deventer (urban)	Deventer is a lively city with ca. 80.000 inhabitants along the Ijssel.	Protecting the historic city centre and the well-being of her citizens.

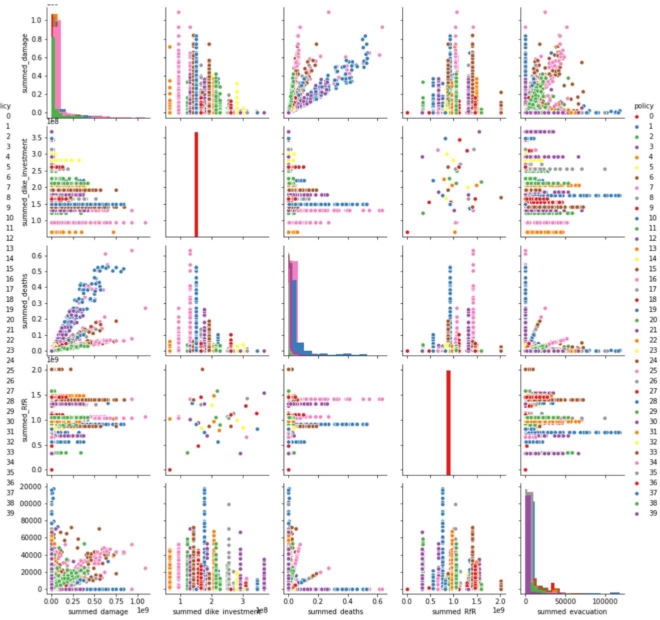
Appendix B: Open Exploration

Not only the outcomes of Deventer were explored, but also the outcomes of the other areas involved. The most surprising findings from these figures are discussed underneath.

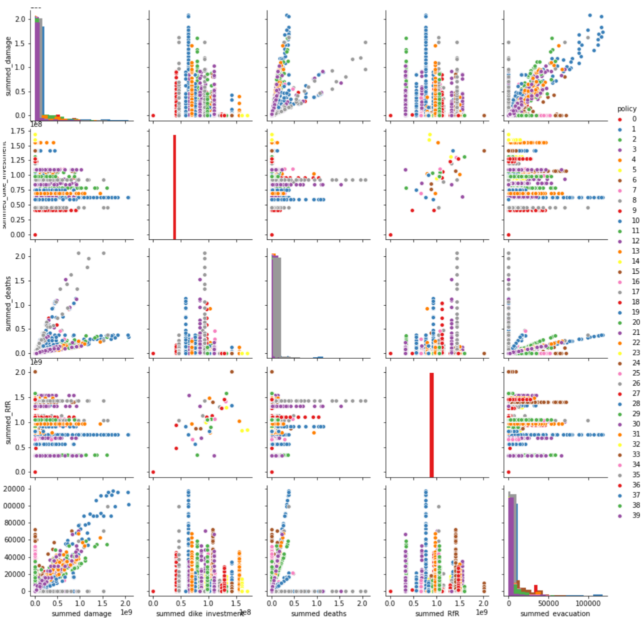
1. For Gorssel, the model estimates that there will be zero deaths in every scenario. For the other areas, there are always scenarios where inhabitants are expected to die.
2. The expected amount of damage for Gorssel tend to be around a factor 100 less than for the other dike rings. Next to that, the amount of dike investments are a factor 10 smaller for Gorssel than for other dike rings.
3. The total expected amount of inhabitants being evacuated seem to be very stable across all the different dike rings. Each area has a range of 0 tot 700.000 people being evacuated.
4. For every dike ring, there seems to be a trend that an increased dike investment will lead to a smaller expected amount of damage as well as amount of deaths.
5. The summed variable Room for the River seems to never show a clear relation with other variables.



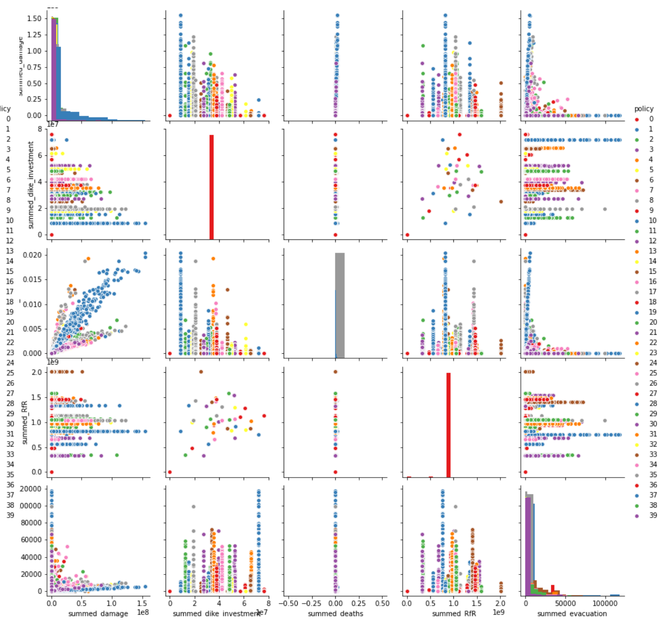
(a) Open Exploration Doesburg



(b) Open Exploration Cortenoever



(c) Open Exploration Zutphen



(d) Open Exploration Gorssel

Figure 25: Open Exploration other Areas

Appendix C: Convergence scenarios MORDM

Convergence scenarios MORDM with 30.000 nfe's.

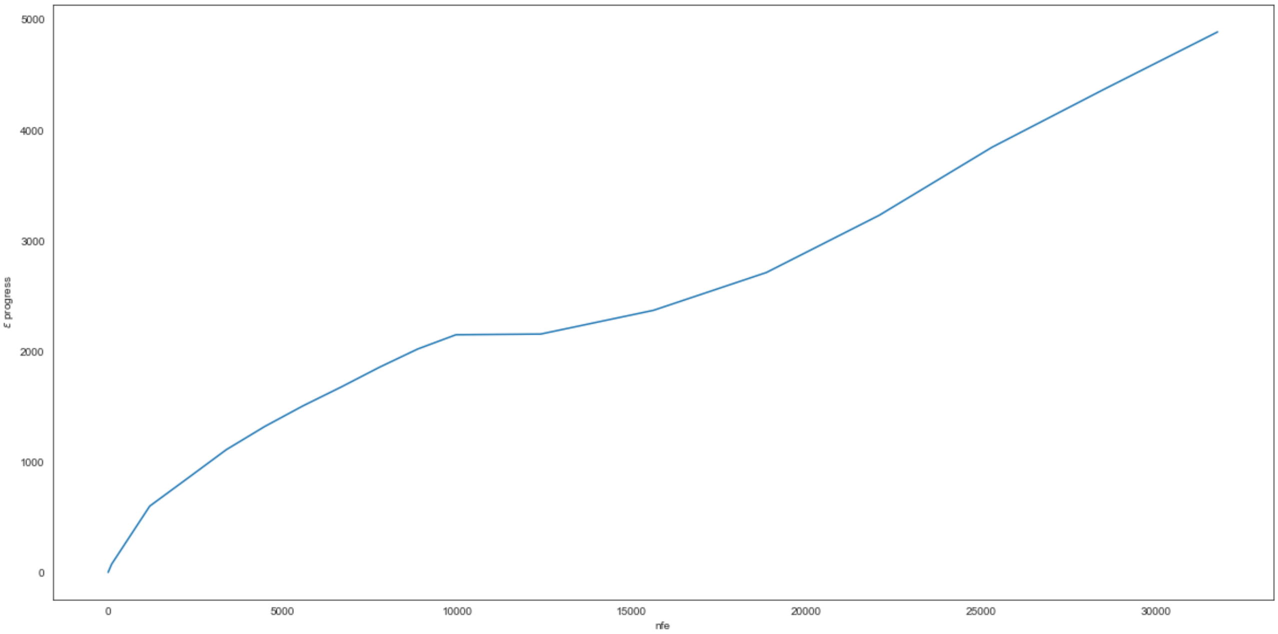


Figure 26: Epsilon best case scenario casualties and cost-wise

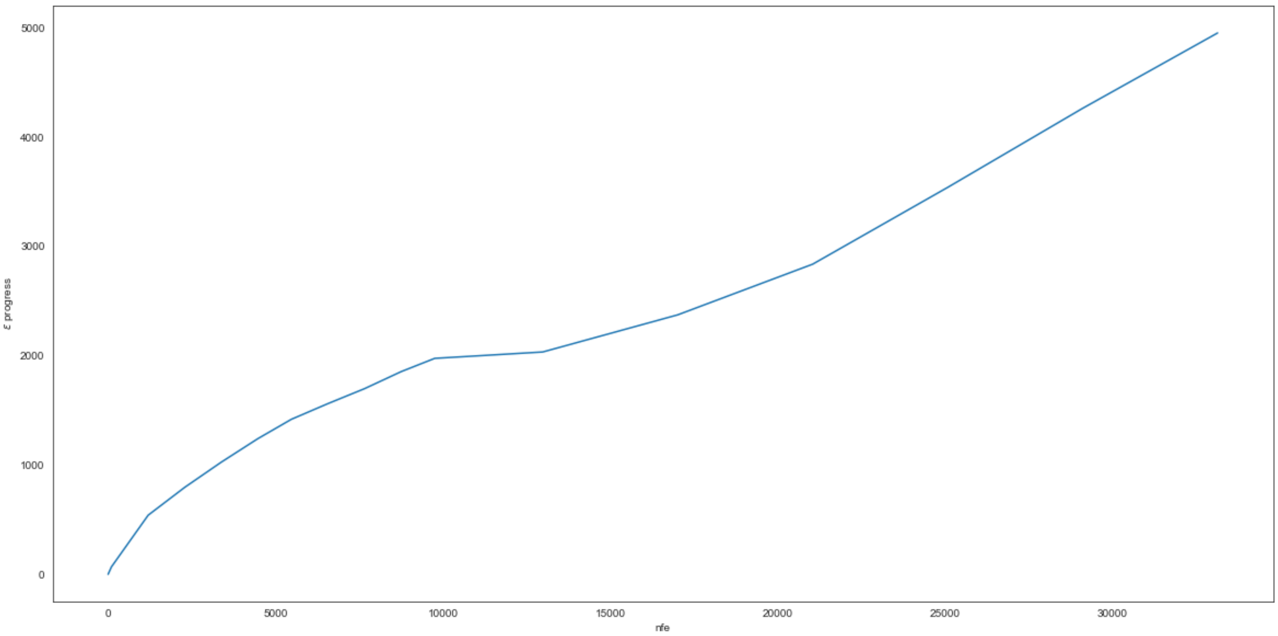


Figure 27: Epsilon worst case scenario cost-wise

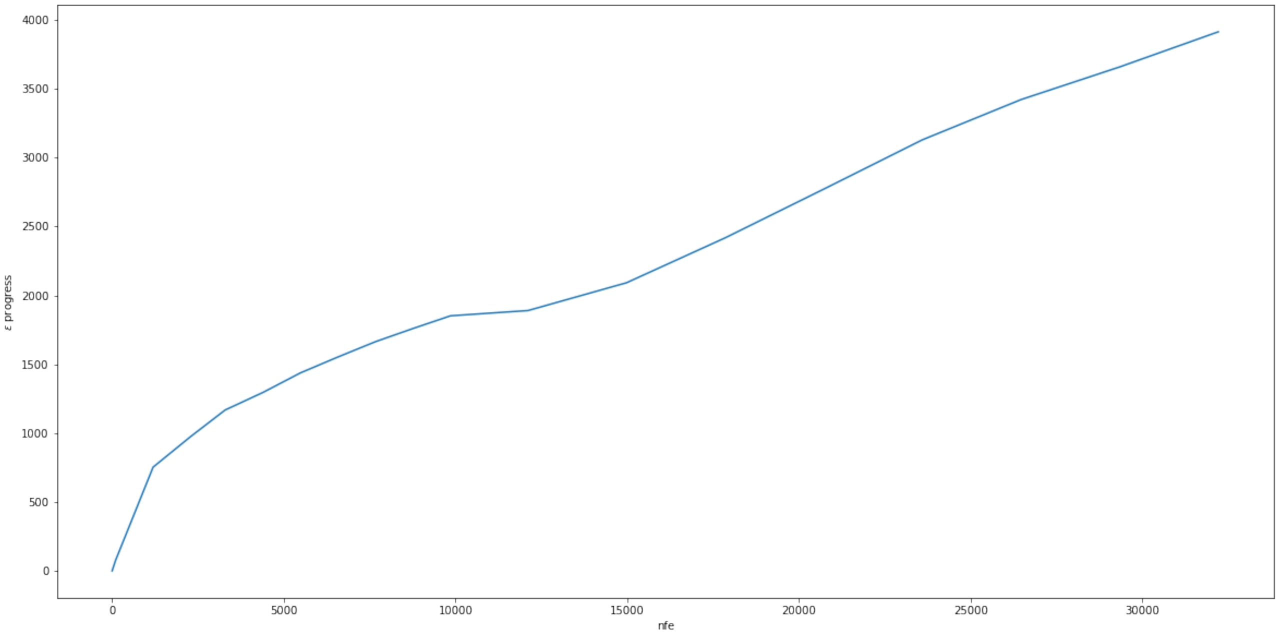


Figure 28: Epsilon worst case scenario casualties

Appendix D: Data to Deventer

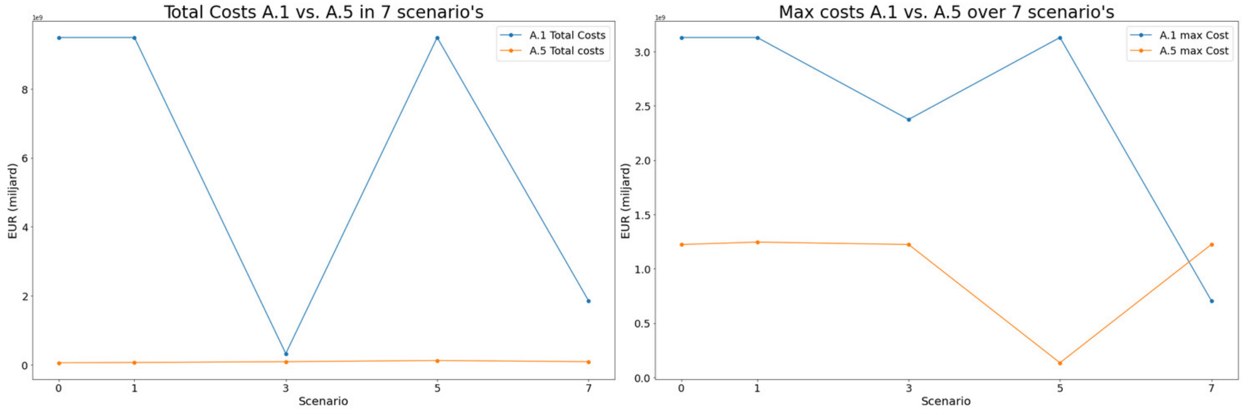


Figure 29: Policy effects on Costs Deventer vs. Gorssel

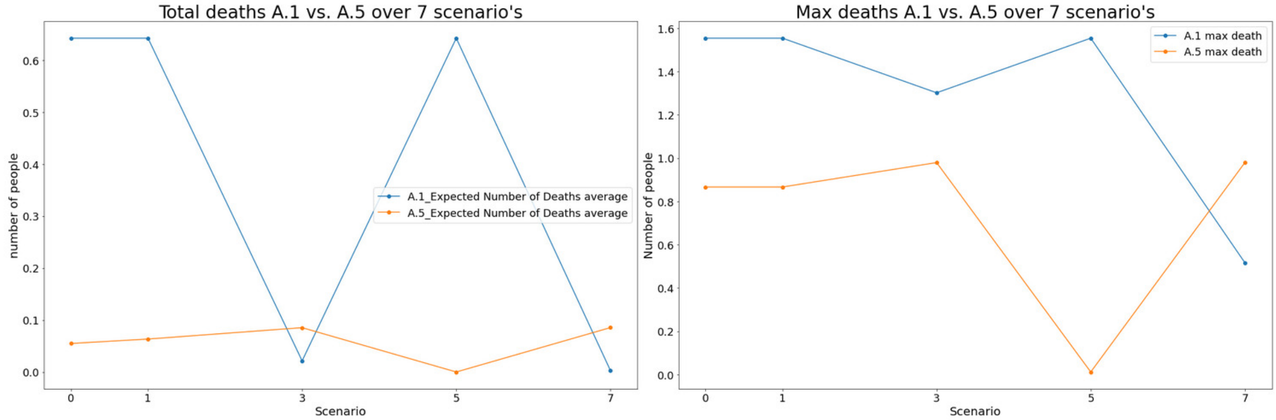


Figure 30: Policy effects on casualties Deventer vs. Gorssel