

Programme of requirements for the design of an instrument that assists spatial planners in assessing flood risk

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Programme of requirements for the design of an instrument that assists spatial planners in assessing flood risk

A RESEARCH TOWARDS THE QUESTIONS IF- AND HOW -AN INSTRUMENT THAT PRESENTS INFORMATION TO USERS FROM A DIFFERENT DISCIPLINE THAN THE DESIGNERS CAN BE IMPROVED

Master thesis submitted to Delft University of Technology
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in

Complex Systems Engineering and Management
Domain: Built environment & Spatial development
Faculty of Technology, Policy and Management

by

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to be defended in public on January 30th 2018 at 15:30 PM.

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PREFACE

This thesis is the capstone of finishing my masters programme Systems Engineering, Policy Analysis and Management at the Delft University of Technology. It contains the results of a research towards which requirements should be met by the design of an instrument that presents flood risk information to spatial planners. The reason for this research was that such an instrument barely being used. The project was commissioned by Deltares, which is an independent institute for applied research in the field of water and subsurface. The report is interesting to read for institutions or companies that are planning to design an instrument that is foreseen to be used by users from another discipline. But also those who are active in the field of spatial planning or water management and are need to cooperate with the other discipline. In the end it can be interesting for future students who are dealing with topics that strike these subjects.

R.A. de Vries
Delft, January 2018

ACKNOWLEDGEMENT

I would like to use this opportunity to express my gratitude towards all the persons that helped me during my research.

First my graduation committee: Tineke Ruijgh-van der Ploeg, Dennis Wagenaar, Wil Zonneveld and Frans Klijn. Secondly I want to thank explicitly Els van Daalen and Martin de Jong for helping me for the last part of my graduation process. Thirdly I want to thank all interviewees, who were willing to answer my questions and giving their opinion about the existing Multi-level safety explorer

Then for the writing part, which wasn't easy. Here I want to thank some teacher who helped me to improve my text. These were Angeniet Kam, Bob van der Laaken, and Maarten van der Sanden. And also my friends: Jeroen, Hugo, and Wolter, who were willing to read parts of my thesis and giving their feedback. Furthermore I want to thank all Deltarians, with whom I had good coffee and lunch conversations about both the subject as well as other topics. It was a good place to do my research.

EXECUTIVE SUMMARY

Introduction

The Netherlands, which literally means 'low country', faces a significant flood risk. To date, this risk has mainly been managed by reducing the probability that a flood can occur. Measures in that vein include building higher and/or stronger dikes. However, these measures have secondary disadvantages, and there will always be a certain residual probability of flooding with a growing potential impact. For these reasons, this initial approach has slowly changed into a search for a more comprehensive package of measures. In addition to reducing the probability of a flood, this new strategy focuses on reducing the potential consequences.

To reduce the consequences of a flood, the spatial planning process should take flood risk into account during spatial planning. For instance, hospitals and electricity distribution stations or transformers can be built in locations with no significant flood risk, and essential infrastructure can be built high enough to lengthen the evacuation period. However, to develop that kind of plan, a stronger cooperation is needed between flood-risk managers and spatial planners. One important aspect of this cooperation is the exchange of information that the spatial planners can use to assess the local flood risk. For this reason, a Dutch governmental organisation that is responsible for water management (Directorate-General for Public Works and Water Management) commissioned to design an instrument to facilitate such information exchanges. That initiative resulted in a website, the Multi Level Safety Explorer (MLS Explorer¹), which is free to use and gives area-specific information about the flood risk. However, to date, this website has barely been used. That lack of use is the central problem addressed in this thesis.

To find if and how the MLS Explorer can be improved, this study first developed a programme of requirements for such an instrument. The next step was to evaluate how good the MLS Explorer scores on those criteria and identify how it could be improved. The following research questions summarise those goals:

What are design requirements for an instrument that helps to assess flood risk during spatial planning processes? And, what does this set of requirements mean for the design and use of the current MLS Explorer

Method

To design a programme of requirements it was first necessary to find out when -and for whom -the Explorer is most useful, what information it should present, and how that information should be displayed. These questions were answered by analysing four Dutch cases. For each case, the planning process was examined to identify the best moment for using the MLS Explorer and the most appropriate users. This analysis was performed according to a fixed spatial planning structure containing multiple phases. For each case, interviews were held with different involved parties, to identify the actor with greatest interest in using the MLS Explorer. A second function of these interviews was to explain the MLS Explorer to the participants and gather their feedback concerning its utility, the type of information it should present, and their preferred display format. The information flow was analysed with use of the result-driven RAKID-model, which stands for Result, Action, Knowledge, Information, Data. Based on the structured case-study research and the interviews, a programme of requirements was created. The existing Explorer was then assessed against those criteria in order to determine whether adjustments are needed.

Background information

Multi-level safety is an approach to effectively reduce the flood risk. It categorises measures as belonging to one of three levels. The first level aims to prevent flooding and therefore contains measures that diminish the probability of such events. The second level uses sustainable spatial planning to reduce the potential impact, and the third level aims to reduce the number of victims by means of well organised disaster management.

¹This explorer can be found on the internet via www.mlverkenner.nl

The MLS explorer is a website that allows users to focus on the specific geographic area, which is targeted by a spatial planning project, to gain insight in the associated flood risk. It contains six steps: (1) the user draws the area of development; (2) the system gives probability of a flood and maximum expected water level; (3) the user selects a type of development; (4) the system indicates the potential risk in terms of the expected damage, number of victims, and present value of the damage; (5) the system gives the result of several MLS measures using the same statistics employed as outputs in the second and fourth step; and (6) the Explorer offers a complete overview of all measures and effects.

Results

The findings in this research can be summarised in four insights that lead to the programme of requirements: (1) The best moment to use the Explorer is early in the spatial planning process; (2) the Explorer is most interesting for local government organisations such as municipalities and water boards; (3) The information that is presented must be understandable and useful, a list of information items is distilled from flood risk analyses that were found in the different case-studies; (4) Finally, the presentation format should be adjusted into a more visionary way to make the Explorer easier for spatial planners to use. On the basis of these results and the interview findings, a programme of requirements was compiled. The instrument should:

1. Be accessible and rapid to use
2. Provide understandable output
3. Be flexible
4. Be credible
5. Be easy to use for communication purposes and official planning documents
6. Provide sufficient information for a decent flood-risk assessment

The current Explorer was assessed on these six requirements. Its overall score was just below medium (on a scale from very low, low, medium, high, until very high), so it is insufficient, but the gap between the current version and the ideal version is not very large. A small adjustment in the design of the Explorer can form a giant leap for the usefulness and attract more users. The Explorer received the best score on the first and last requirements, since it is accessible (requirement 1) via the internet and it takes about 5 minutes to analyse one geographical area, and it presents sufficient information for a decent flood risk assessment (requirement 6). However, for the remaining four requirements, improvement is possible. The understandability (requirement 2) for spatial planners could be increased by using terms and figures that are commonly employed in that field. Increased flexibility (requirement 3) would serve two purposes: making the instrument more interesting for users with varying degrees of background knowledge, and making it more suitable for exploring an area by testing different scenarios. The Explorer's credibility (requirement 4) should be improved by fixing bugs that make the instrument unreliable. The instrument's suitability for communication (requirement 5) between parties at the beginning of the spatial planning process could also be enhanced. Such adjustments would facilitate meaningful conversations instead of first needing to wait for the release of research reports. Based on these requirements, this thesis gives a suggestions for a new design in order to give a concrete idea for adjustments that could improve the quality of the MLS Explorer.

Conclusions and recommendations

The main conclusions are as follows:

- The Explorer has significant potential, with several parties interested in using it.
- However, the Explorer's performance is inadequate as regards certain essential requirements related to its utility. Thus, it should be adjusted to meet those targets.
- Six requirements can be used to organise the improvements for the Explorer.
- If Explorer permits the integration of precipitation models, private parties may be interested in it.

This leads to the following recommendations:

- Validate the suggested programme of requirements.
- Remove the identified technical bugs.
- Adjust the Explorer based on the programme of requirements in consultation with potential users.
- Start a dialogue with provinces about the suitability and usefulness of the MLS Explorer for municipalities that need to write a flood risk paragraph.
- Make the MLS Explorer suitable for developing the flood-risk paragraph in spatial plans.

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GLOSSARY

LIST OF ACRONYMS

DGPWWM = Directorate-General for Public Works and Water management: See 'Rijkswaterstaat' in list of Dutch names.

DIKAR = Data, Information, Knowledge, Action, Result: Theory that describes the transformation, and possible management gaps between data and result.

DIKW = Data, Information, Knowledge, Wisdom: Theory that describes the main differences between these four levels.

EIA = Environmental Impact Assessment: The research which is done in order to write an Environmental Impact Statement, see EIS.

EIS = Environmental Impact Statement: A report in which the environmental impact from different alternatives are compared to each other and the status quo.

FR = Flood Risk.

FRM = Flood Risk Management.

HIS-SSM = Hoogwater Informatie Systeem - Schade en Slachtoffer Module (High water Information system - Damage and Victim Module): An general used information model for the Netherlands, which can be used to calculate expected damage and victims. The development of this module was commissioned by the Dutch national government and provinces.

HWBP = Hoogwaterbeschermingsprogramma: See Flood Protection Programme

LIR = Lokaal Individueel Risico [Local Individual Risk]: see list of Dutch names.

LSG = Lokaal Schade gevaar [Local damage threat]: see list of Dutch names.

MIRT = Meerjarenprogramma Infrastructuur, Ruimte en Transport (Multi-annual programme Infrastructure, Spatial planning and transport): Programme in which the national government cooperates in spatial projects with de-central governments. This cooperation is focused on the financing of projects with national interest.

MLS = Multi-Level Safety (also 'multi-layered safety' or 'multiple-tiered approach' are used for the same concept): concept with three 'levels', (1) flood protection/prevention, (2) sustainable spatial development, and (3) Disaster management. These different levels contain measures that reduce the flood risk in a different ways.

POR = Programme Of Requirements.

RWS = Rijkswaterstaat: see list of Dutch names.

SP = Spatial Planning.

STOWA = Stichting toegepast onderzoek waterbeheer [Foundation for Applied Water Research: See 'Stichting Toegepast Onderzoek Waterbeheer' in list of Dutch names

VINEX = Vierde Nota Ruimtelijke ordening Extra (Fourth Memorandum Spatial Planning Extra): Visionary document from 1991 in which the national government prescribed the desired direction in spatial planning.

VINO = Vierde Nota over de Ruimtelijke Ordening (Fourth Memorandum on Spatial Planning): Visionary document from 1988 in which the national government prescribed the desired direction in spatial planning.

VNK = Veiligheid Nederland in Kaart (Safety Netherlands on a map): A project that analysed and subsequently mapped the flood risk in the Netherlands.

WM = Water Management.

LIST OF DUTCH NAMES

Bestemmingsplan [Land-use plan (also zoning plan)] = This plan points out what can be built where, how the land may be used and which regulations apply.

Delta programma [Delta Programme] = A yearly programme, which is being carried out jointly by several public authorities and other organisation in the Netherlands. The Delta commissioner has the main responsibility for the programme.

Deltacommissaris [Delta commissioner] Person who responsible for the yearly Delta programme and has the role of main government commissioner who represents the water management in the Netherlands.

Dijkringgebied [dike-ring area] = An area that is protected against flooding, from sea or river, by primary

flood defence and/or high ground. The Netherlands has approximately 100 dike-rings.

Dijkvak [Dike section] = Part of a dike-ring with more or less comparable properties. For example the length of every individual dike section within the same dike-ring is almost the same, if it has no reason (like a weak component) to deviate.

Gebiedsagenda [areal agenda] = Policy document which states the vision and objectives in a certain area for the coming decades.

Hoogwaterbeschermingsprogramma [Flood Protection Programme] = The Flood Protection Programme involves a long-term alliance between the district water boards and the central government (RWS [DGPWWM]). This programme gives a periodically programme that is aimed at protection against flooding and it is evaluated and adjusted every round of 5 years.

Lokaal Individueel Risico (LIR) [Local individual risk/Flood Fatality Hazard] = The probability that a person who would be a whole year on the same location becomes victim of a flood, taken into account the evacuation possibilities.

Lokaal Schade Gevaar (LSG) [Local damage threat/Flood Damage Hazard] = Yearly probability of damage for the existing value. To calculate this, the damage per square meter is estimated. This amount will be multiplied with the chance and total surface of built area. If the chance is 2% per year, the expected damage is around 700 euro per square meter built surface area and half of a hectare is built then the LSG for that area will be $0.02 * 700 * 0.5 * 10,000 = 70,000$ euro per year

Normaal Amsterdams Peil (NAP) [Amsterdam Ordnance Datum] = A vertical reference height(datum) to which the height measurements are related.

Omgevingsplan [Surroundings plan] = Plan that will be used by a municipality to explain the short term spatial plans for their area. Officially this is the replacement of the zoning-plan after establishment of the omgevingswet, but there are already municipalities that have a Surroundings plan.

Omgevingsverordening [surroundings regulation] = Provincial variant of the short term plan (after establishment of the Omgevingswet) in which the spatial development for the whole province is regulated.

Omgevingsvisie [Surroundings vision] = A visionary plan that will be used by National, Provincial and Municipal government to explain their long term (integral) vision for the spatial planning. Officially these visions will be used after establishment of the Omgevingswet, but there are already some surroundings visions made.

Omgevingswet [Environmental planning Act] = New act that is expected to be established in 2019 and will change a lot in the Dutch system of spatial planning. One of the main reasons for the design of this act is to make it easier and more transparent. For this reason there will be many separate acts, rules, and regulations incorporated in this new Environmental planning Act.

Overschrijdingskans [Probability that water exceeds the design level of the dike] = Based upon the measures of past water levels an estimation is made that the water will reach certain level in a chosen interval. The Dutch government chooses a desired interval and the dikes are designed based upon the water level that belongs to that interval.

Overstromingskans [Probability of flooding] = Probability that a flood can occur. In the current Dutch approach, this probability for every dike-ring is estimated on the basis of multiple fail mechanisms.

Inpassingsplan [land-use plan] = plan that is used by in Provincial and National form. It consists of destination and rules that indicate for each piece of land for which purpose it can be used. Most of the times this is a mix of management which counteracts undesirable developments and makes desired developments possible.

Plaatsgebonden risico (PR) [Location specific risk]= The probability that a person who is on the one location, the whole year long, will become victim of a flood on that location, unlike the LIR evacuation factor is not taken into account.

Rijkswaterstaat [Directorate-General for Public Works and Water Management(DGPWWM)] = This organisation is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. This includes the main road network, the main waterway network and water systems.

Stichting Toegepast Onderzoek Waterbeheer (STOWA) = This is the Dutch acronym for Foundation for Applied Water Research, which is the knowledge centre of the regional water managers (mostly the Water Boards) in the Netherlands. Its mission is to develop, collect, distribute and implement applied knowledge, which the water managers need in order to adequately carry out the tasks that their work supports.

Streekplan [Regional plan] = Until the Spatial planning Act [Wet ruimtelijke ordening](2008), a document that was established by the Provincial council, which described the outline of the future development of in a certain area. It contained for example the outlines of locations where villages and cities were allowed to

expand and what areas were reserved for agriculture, nature and recreation.

Structuurplan [Structure plan] = Until 2008, a by the municipal council established plan in which future local developments for the spatial development were described.

Structuurvisie [Structure vision]= Since the Spatial planning Act of 2008 this replaced the Streekplan. The province explains the long term and integral foreseen developments. The provinciale inpassingsplan is used for the more short term spatial development.

Waterschap [Water board] = Regional government bodies charged with managing water barriers, waterways, water levels, water quality and sewage treatment in their scoped regions.

LIST OF SPECIALIST TERMS

Dam = A barrier that prevents water to flow from one place to another, it is built between two shores or river banks

Dike = Collective name for different type of water barriers that keep water away from the land side. Embankment and levee are also named a dike, whilst they actually differ in literal meaning

Dry proof building= building such that the water will not enter the building, watertight walls and casements.

Embankment = Man-made barrier that keeps river water in the river instead of flowing over the country.

Levee = An elongated naturally occurring ridge or artificially constructed wall, which keeps the water away from the inner dike area. Levee is the barrier along the river, whilst dike is more used for the sea side.

Polder= Low lying piece of land that is reclaimed from the sea and is protected by dikes.

Rampart = Defensive wall to keep the water out, mainly small scale around a fort or castle. It also serves as defensive boundary for the enemy.

Water depth = The water depth that can occur in case of a flood, this level is relative to the ground level.

Water level = The level of the water relative to the sea-level, or NAP.

Weir = A barrier across a river designed to alter the flow characteristics

Wet proof building = Building such that the first level is resistance for a flood, for example tiles instead of wooden floor and installing the electricity on a higher level than the potential water level in case of a flood.

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1

INTRODUCTION

1.1. PROBLEM DESCRIPTION

A new approach, Multi-Level safety [Meerlaagsveiligheid; MLV], was introduced in the Netherlands in 2009 and formally explained in the National Water Plan (Min. van V & W, 2009). The MLS approach includes three levels with measures aimed at reducing the flood risk. The first level focuses on reducing the probability of a flood event. The second level emphasises reducing vulnerability during a flood while the third aims to improve the preparedness in case of a flood. A more elaborated explanation will be given in chapter 3. The second and third level of this concept are often forgotten and the spatial planner automatically stick to the first level (expertisenetwerk waterveiligheid, 2012; Naeff, 2012; van Buuren & Ellen, 2013). The below box contains an example of how the potential impact could significantly be reduced by only building a data centre 2 kilometres to the south.

Example:

Microsoft owns a large data centre, which costed 2 billion euros (Edmonds, 2013), in the province of North Holland. More specifically, it is located inside the Wieringermeerpolder (dike-ring^a 12). The future flood risk for this data centre can be expressed in terms of present value^b of the expected damage, which is almost 3.5 million euros. However, if the data centre were built 2 kilometres to the south, in West Friesland (dike-ring 13), the present value of the flood risk would be around 400,000 euros. This example raises the question of whether the location inside dike-ring 12 is worth that much more, such that the higher risk is acceptable.

^aThe Netherlands is geographically divided into approximately hundred dike-rings. These are enclosed areas in which the water can freely spread in the case that a flood occurs. If one dike-ring floods due to a dike failure, another adjacent dike-ring will, in principle, remain dry

^bThe present value is equal to the damage multiplied by the probability of the event and expressed in euros. This method allows the costs of risk-reducing measures to be compared.

In order to stimulate flood resilient spatial planning, the Directorate-General for Public Works and Water Management (DGPWWM) [Rijkswaterstaat] commissioned to develop an instrument that helps to make decisions upon measures within these three levels. The name of this online instrument is 'Multi-Level Safety Explorer' (MLS Explorer, www.mlverkenner.nl). This website was launched in 2014. In short, The MLS Explorer is an instrument that spatial planners can use to better understand the local flood risk. After drawing foreseen spatial developments on a map, planners can retrieve several pieces of information about the flood risk associated with such changes. A more extensive explanation of the MLS Explorer is found in chapter 3.3. When individuals working in the realm of spatial planning hear about this tool, they often respond enthusiastic. However, the MLS Explorer is barely being used. Deltares, which commissioned this research, wants to investigate this problem.

This limited use could be due to a range of factors. For example, potential users may be unfamiliar with the instrument, the Explorer may be too difficult to use, or it may not provide the desired information. A combination of these causes may also be to blame. If the Explorer is too complex, the problem could be solved by training potential users or simplifying the tool. If it is providing information that is not interesting, the Explorer could be adjusted. However, the exact reason behind the lack of use is difficult to pinpoint. The exploratory phase of this research made clear that the Explorer's developers did not rely on an initial set of requirements. The Explorer was developed by flood-risk specialists, which resulted in informal and

subjective requirements that are not aligned with the needs of the end user. Therefore, it was decided to do one step back and first develop a programme of requirements for the design of such an instrument and then assess if and how the existing tool might be improved.

1.2. RESEARCH QUESTIONS

The problem that the MLS Explorer is barely used resulted in the goal to find out if and how the MLS Explorer can be improved. This was addressed by answering the following questions:

What are design requirements for an instrument that helps to assess flood risk during spatial planning processes? And, what does this set of requirements mean for the design and use of the current MLS Explorer?

In an early stage of the research the researcher already gained ideas that the main cause of non-usage could be found in the design of the Explorer and not in the familiarity. Therefore the assumption was drawn that the Explorer had to be adjusted. In the end this assumption may prove wrong. So this is a research with its focus upon the supply side of the instrument instead of the demand side of user. If this assumption was falsified, with the conclusion that the Explorer's quality is good, this could result in the overall conclusion that the Explorer does not have to change, and more research is needed towards the users. This does not mean that the user was not a research object since it is necessary to know what a user needs in order to determine the quality of the instrument.

To answer the main research question, it was split into six sub-questions, divided into two categories. First, four questions helped to define a solid programme of requirements, and subsequently, two questions use the earlier gained answers to focus on the MLS Explorer.

Part I: What are design requirements for an instrument that helps to assess flood risk during spatial planning processes?

1. **When should the flood risk be assessed during the spatial planning process?**

A spatial planning process takes quite some time, meaning that there are many different phases with their own points of focus. To identify the main requirements for an exploratory tool, it was necessary to determine the most suitable moment for using such an instrument.

2. **Who are best suited for conducting an exploratory flood-risk assessment?**

After the most suited moment for exploratory flood-risk assessment was found, the next step was to analyse the involved parties during that stage and for whom an instrument for assessing this flood risk would be useful.

3. **What information should the instrument present?**

When the users are known, it can be analysed what information they already use, what would be interesting for them to use and what they understand. All this is covered by answering the question what information should be presented by such an exploratory tool.

4. **How should the information be presented?**

The last question in forming the design of the programme of requirements is what form of presentation would be most suitable. In this question it was important to be aware of the fact that answers to this question can vary significantly between different users.

After these questions were answered, a programme of requirements was created. This set of requirements is employed in a general format and is appropriate for assessing an instrument like the MLS Explorer. Together, these requirements and the existing MLS Explorer were used as input to answer the second part of the main research question.

Part II: what does this set of requirements mean for the design and use of the current MLS Explorer?

5. **How does the current Explorer score in terms of the newly developed requirements?**

The current Explorer was compared with the requirements to evaluate its quality. This method allowed the researcher to determine whether that the instruments lack of use has been due to quality-related issues or to other factors (e.g. the need to train potential users).

6. **How can the current Explorer be improved?**

After it is explained how the current Explorer scores, several suggestions for improvement are given.

These suggestions are made specific with visuals of how an adjusted design of the MLS Explorer could look like.

The answers to these questions are given throughout the report. Figure 1.1 illustrates which chapter answers each question.

1.3. READING GUIDE

After this introduction, chapter 2 explains the used methods. Chapter 3 addresses three paragraphs that form the background information for the whole research. Chapter 4 gives an introduction of the two regions, and the four cases within these regions, that were analysed during this research. Chapter 5 and 6 analyse respectively with the spatial planning model and the RAKID model the cases that were explained in chapter 4. Chapter 7 gives the programme of requirements that is the result from the analysis in chapter 5 and 6. This programme of requirements is subsequently compared with the existing MLS-explorer in order to assess this instrument and come with suggestions for improvement. Finally chapter 8 will answer the main research question, explain the main conclusions and give recommendations.

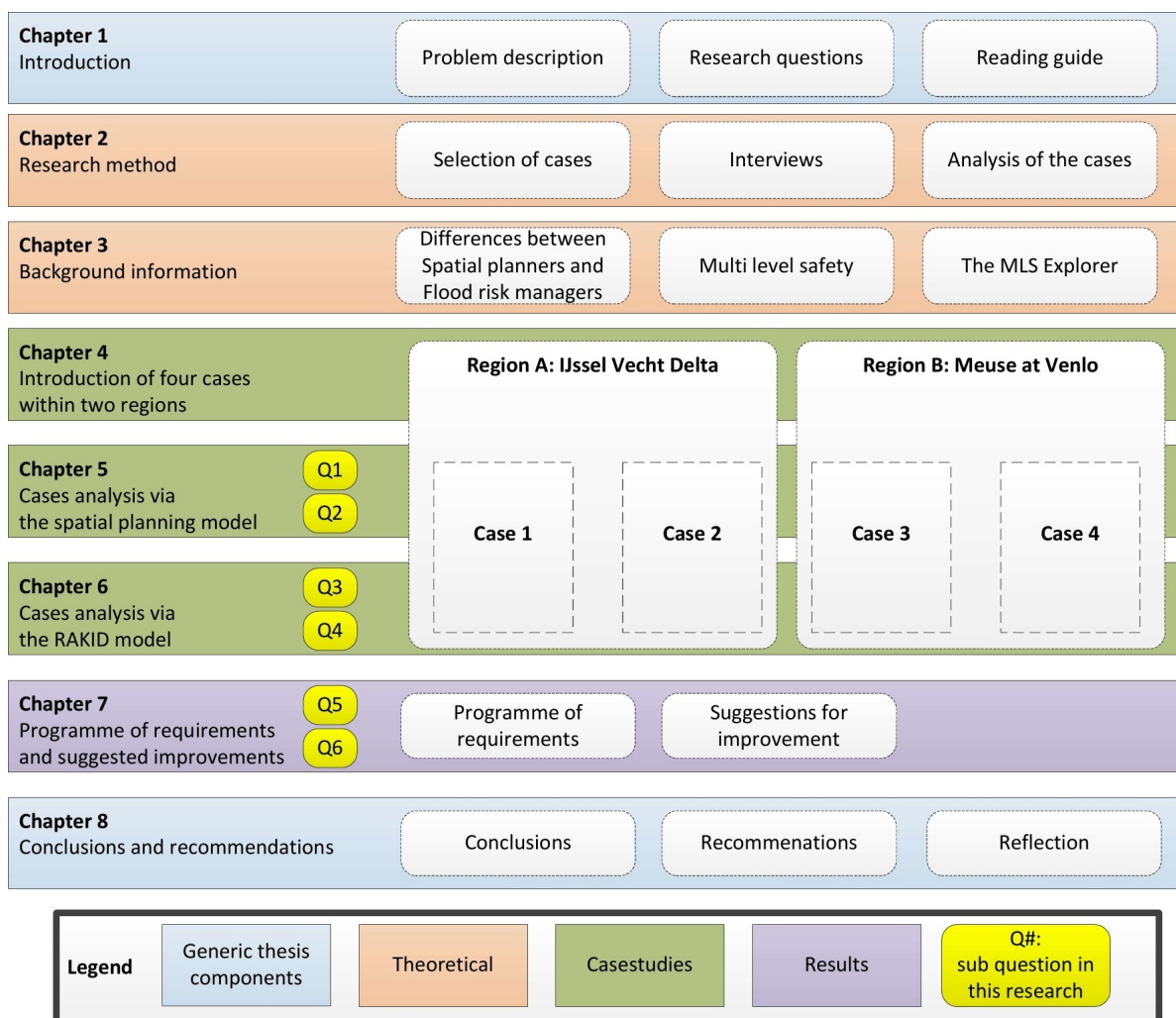


Figure 1.1: Overview of the structure of the report. The colours represent introduction, theory, practical research or results and the chapters are indicated with by the numbers. The questions answered in each chapter are specified with the Q-numbers.

2

RESEARCH METHOD

The methodology that was used to design the programme of requirements exists of several steps and different methods. After the prior exploratory literature research, first two regions were selected, and for each region two separate cases were selected. These four cases were analysed according to a spatial planning model (see chapter 5) and an information management model (see chapter 6). Simultaneously to these analyses, various people were interviewed. These interviews provided deeper insight into the informal processes and allowed the researcher to ask more detailed questions upon statements that were found in the documentation. The results from this analysis were used to compile the programme of requirements that was subsequently used to assess the MLS Explorer. In the end the programme was validated in an interview with a person from the organisation that initially commissioned to design the instrument. This chapter will first elaborate upon the method that was used to select cases and the secondly upon the interviews, who have been interviewed and what questions were asked.

Throughout this chapter it will be explained how three types of validation were used to reach credible results (data-, environmental-, and methodological- triangulation) (Guion, 2002). An overall type of validation that was used is the *data triangulation*. This was implemented by selecting multiple cases in the case study analysis and multiple interviewees with different background for the interviews. Although the group of respondents was quite small and therefore selecting a comparable group from every organisation was not really the case. From each involved party maximal two persons were interviewed. In the second region (Venlo) there was no non-governmental organisation, but a advisory bureau, which functioned as source for a broader line of input.

2.1. SELECTION OF CASES

During this research two locations (Venlo and Zwolle) with different characteristics were selected for analysis. This *environmental triangulation* (Guion, 2002) is one of the three type of validation that was used. This same validation was also applied by the selection of cases that occurred in different eras. The case-study design used in this research is a variant on the holistic multiple-case design described by Robert K. Yin (2013). First, examining multiple regions indicates whether the results are context-dependent. Considering such aspects was necessary in this study, since the research was exploratory in nature, with a variety of parties involved in spatial planning. Spatial planning processes vary quite considerably across the Netherlands, making it difficult to identify mutually agreed requirements for an instrument like the MLS Explorer. After two cases (single spatial plan) were analysed in each region (location in the Netherlands with its own flood risk characteristics), it was interesting to look for similarities between them. This method also

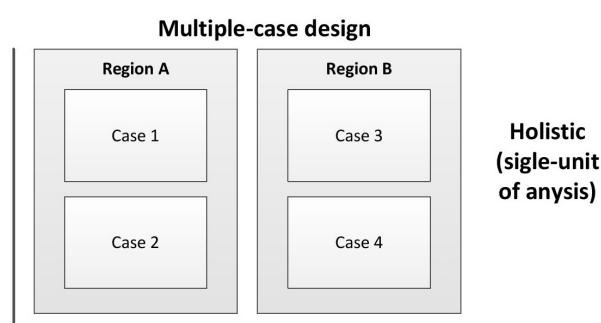


Figure 2.1: Slightly adapted design of the case-study design. Based on the designs presented Yin (2013); see upper right-hand corner of Figure D.1 in appendix D. In here the regions in the Netherlands with different flood risk characteristics and the cases are two different plans at those locations.

made it possible to determine whether particular observations were situation-dependent, and therefore not relevant for an instrument designed to be used across the entire country. Secondly, two cases were necessary within each region to reduce the probability of unrepresentative results from a single case. A more elaborate explanation of the case-study framework is in appendix D. This chapter now explains how the two regions, and the cases within those regions, were selected.

The selection of regions was primarily based upon the following three criteria:

- There had to be a flood risk in the location
- There had to be new spatial plans, either on the political agenda or newly completed.
- There had to be sufficient planning documents available to perform adequate research.

In addition, it was also important for the regions to differ from each other, because the goal was to determine whether the results were due to contextual characteristics. Therefore, the researcher sought to select regions that differed in terms of the flood-risk origin. Floods can vary in terms of, for example, predictability (potential flooding from a river can be predicted earlier than flooding from the sea) or in the potential impact (which can differ due to population density or elevation). To select locations, a lengthy list of candidates was compiled (see appendix D), and it was eventually reduced to two locations that best fit with the selection criteria. These were the IJssel Vecht Delta, which is an area around Zwolle, and the area around the Meuse at Venlo.

2.2. INTERVIEWS

The third type of validation that was used to improve the credibility of a qualitative study is the *methodological triangulation* (Guion, 2002), which was performed by using different sources. The first source was available documentation of all four cases, the second source are the interviews conducted simultaneously with the case study research.

2.2.1. THE INTERVIEWEES

After the cases were selected and an exploratory case study analyses was performed via available documentation, multiple interviews were held with different types of stakeholders. There were multiple reasons that the interviews were held with respondents with different backgrounds. The first 'validation' reason is because of the *data triangulation*, using answers from one interviewee could be placed in a broader perspective and compared to answers from different stakeholders. And the second reason is that it was not clear which stakeholder was most interested to use the Explorer. In total twelve interviews were held, of which nine are directly linked with the case studies. Besides these nine, there was one at the beginning of the research (No. 1) to gain more insight in how water boards deal with Multi-Level safety, another one (No. 10) was in the end of the research in order to verify ideas for change with Durk Riedstra, who was at the National side involved in the development of the initial MLS-explorer, and the last one (No. 12) was to verify some ideas that were raised during the interviews with someone who is both active in the university as well as the Dutch National government, this was more linked to the idea of usage of the MLS explorer during the the watertest¹ [Watertoets] process. The interviewees that have been approached for the cases were working for different organisations (e.g. Province, Municipality, water board, advisers). This was necessary in order to find out who was most interesting to use the MLS Explorer and it gave the opportunity to validate results from other interviewees. The whole list of interviewees is found in figure 2.1.

¹The water test was introduced in 2001, see Appendix A

Table 2.1: List with persons who have been interviewed in this research

Sequence	Case	Name of interviewee	Working for
1	No case, exploratory	Jorien Burger	Water board 'Delfland'
2	IJssel-Vecht Delta	Toon van Beek	Municipality of Zwolle
3	IJssel-Vecht Delta	Gerrit Vrielink	Water board 'Drents Overijsselse Delta'
4	IJssel-Vecht Delta	Lodewijk van Nieuwenhuijze	'H+N+S' landscape architects (one of the founders)
5	Meuse at Venlo	Arjan van Hal	Water board 'Peel en Maasvallei'
6	IJssel-Vecht Delta	Menno ten Heggeler	Province of Overijssel
7	IJssel-Vecht	Carolien van Rijen and Mark Bruggink	Housing association 'SWZ'
8	Meuse at Venlo	Bart Bomas	'BVR' advisers
9	Meuse at Venlo	Michiel van der Hagen	Municipality of Venlo
10	Verification of suggested adjustments for the MLS Explorer	Durk Riedstra	Directorate-General for Public Works and Water Management
11	IJssel-Vecht Delta	Merel Enserink	'Het oversticht' landscape architects
12	Verification of the watertest	Pieter de Jong	Ministry of Infrastructure and Environment and Delft University of Technology

2.2.2. INTERVIEW QUESTIONS

All interviews had comparable general line of questions. But due to the variety in background of the interviewees, all the interviews had their own point of focus. The general line of the interviews, which took around one hour, can be divided in three sections. After a brief introduction, the questions first regarded the cases that were selected for the analysis. In this part questions were stated like; what was the problem, when was the problem identified, who were involved, who took the decision, which input was used to make this decision. This was important to get a better insight via the informal channels that result in more background information in addition to the things that have been written in the reports. In the second part of the interview the focus of the questions shifted towards the concept of MLS and cooperation. This was done with questions like; Do you know what MLS is, what is your organisation doing with this concept, do you cooperate with other parties and if so, what kind of information do you exchange. In last part of all the interviews the interviewer explained the MLS Explorer (by showing an animation that explains how the MLS Explorer works in a concrete case) and asked the interviewee's opinion on the MLS Explorer, if things were strange or difficult for them, if they thought it would be useful in their work, if they had suggestions for improvement. Because of the variety in interviewees, all interviews all had their own point of focus. The interviews were qualitative, which means that a general line of questions was used to start the conversation, but during the interview there was room to focus on more specific parts that were considered important.

2.3. ANALYSIS OF THE OBTAINED INFORMATION

After conducting the interviews, the answers were structured in a table with the interviewees in the columns and questions in the rows. This way the answers from different respondents to comparable questions could be compared and analysed to see if many respondents shared the same opinion or if their answers differed significantly. In case there was a difference, the answer upon the same question from a respondent that was active at a comparable organisation in the other region was analysed to see if the difference in answers could be declared by the area specific characteristics. Simultaneously with this analysis, there was an analysis of the case study material that helped to answer the first four sub questions. This analysis was performed with use of two models. First, the 'spatial planning model' and second, the 'RAKID model'.

2.3.1. SPATIAL PLANNING MODEL

The Dutch language has multiple words that describe spatial planning from slightly different perspectives. The Dutch word 'ruimtelijke ordening', more literally translated as *spatial regulation* or *spatial organisation*, refers to practical actions (van Schijndel & van der Wal, 2011) or to a discipline [vakgebied] in the form of a field of expertise (Spit & Zoete, 2006). A somewhat comparable word, 'planologie', literally translated as *planology* denotes the scientific field [wetenschapsgebied] that supplies the knowledge needed for spatial organisation. A third Dutch term is 'ruimtelijke planning', literally translated as *spatial planning*, which means discipline in the form of a working field [werkterrein]. In this report first spatial planning is used from the theoretical point of view, similar to 'Ruimtelijke ordening', by explaining the phases that can be identified. Secondly, in the case study research spatial planning is used from the practical point of view, similar to 'Ruimtelijke planning', since the cases were used to analyse how these processes work in reality.

Spatial planning is a long-standing discipline in the Netherlands, and its goal is to create the best possible living environment. Spit & Zoete (2006, p. 15. translated from Dutch) have provided the following definition:

Spatial planning [ruimtelijke ordening] encompasses the process of searching for a spatial design for a changing society and of making choices about how and where certain functions accord its full weight, especially from the perspective of long(er)-term development, including its reflection.

This definition is in line with two statements from de Roo & Voogd (2004, p. 131). Those authors explained that making decisions is the 'core business' of the spatial planning process and that it has a cyclic character, necessitating flexibility. With this knowledge in mind, the researcher of the this report distilled a certain pattern of six steps from a variety of different spatial planning models (de Roo & Voogd, 2004; Spit & Zoete, 2006; van Schijndel & van der Wal, 2011), See appendix B for an overview of the models. Those six steps can be shortly explained as follows:

1. **Problem identification:** In this step, the problem that has emerged is recognised. The time needed for this step varies, and determining when a problem started is often subjective. Formal recognition is often undertaken by a governmental organisation.
2. **Problem analysis:** The next step is to determine the exact nature of the problem. At this point, it can be discussed or put forward as a research topic. The first approach is more informal, while the second is a more formal way of analysing a problem. Quite often, the processes within this step are performed too quickly, which can result in a solution that only solves one side-effect instead of the real problem.
3. **Set objective(s):** After there is mutual agreement upon the problem, the objectives can be stated in a way that encourages people to think about potential solutions.
4. **Develop alternatives:** Different methods of reaching the stated objective are developed in the form of multiple alternatives. In spatial planning processes, several possible alternatives are often possible.
5. **Compare alternatives:** The next step is to compare these alternatives with each other using a set of pre-established criteria.
6. **Choose an alternative:** The alternative that scores best can be chosen, or else all options with a certain score can be further discussed before a final choice is made.

The literature's demarcation of individual phases represents an idealised process, and in practice, the boundaries are not as clearly defined. Spit and Zoete wrote that *'there is a strong interaction between phases...in practice, the phases will go through each other and past each other. Every planning process is a cyclic and interactive process, wherein the same phase occurs several times'*(Spit & Zoete, 2006, P. 86 translated from Dutch). This cyclic and repetitive character makes it difficult to identify one single phase within a single report, as each report usually contains multiple phases.

Another categorisation that can be made within the Dutch spatial planning process considers the governmental level that carries out the steps. Practically every spatial planning process involves a variety of actors, which all have their own facilities and responsibilities. In the Netherlands this can be split up into four general levels: The whole country, provincial level, municipal level, or a smaller level like private projects. This is called 'Local' in this report.

2.3.2. KNOWLEDGE MANAGEMENT EXPLAINED IN THE RAKID MODEL

The second model that was used to perform a structured analysis to answer two questions is the RAKID model. This model is based upon the DIKAR model that was first described by Venkatraman (1996). The letters stand for Data, Information, Knowledge, Action and Result. In this sequence it describes the transformation process from raw data towards information with specific meaning, then from information towards knowledge that is needed for taking specific actions, and eventually such an action has end up in a desired result. Another way of using this DIKAR model is to start at the desired result (Result-driven approach (Chaffey & Wood, 2005, p.507)) and think about the action, knowledge, information and data that is needed to reach this result. This was described by Murray (2000) who explains that the left-to-right approach is focusing too much on producing information and knowledge instead of the finally desired result. Therefore it would be better to start thinking from at the result and moving towards the data. This is a good approach for this research since last chapter's model ended with an action and now it can be analysed which information the Explorer should present in order to be useful.

The data, information, knowledge, wisdom (DIKW) hierarchy from Hey (2004) is a theoretical framework with high level of similarity with the DIKAR. The pyramid, with Wisdom in the top and Data at the bottom it visualises that a large stock of data can be turned into a smaller quantity of information, which can subsequently become an even smaller body of knowledge, and in the end result in very rare wisdom. The DIKW theory was used in this research, because it clearly clarifies the difference between data, information, and knowledge. Those terms are explained below on the basis of Jonathan Hey (2004), while ‘action’ and ‘result’ are defined in more general terms based on an article about information management by Murray (2000):

- *Data* refers to unprocessed numbers and/or characters without any meaning. Data are a resource for producing information. Moreover, they are easily transferrable, discrete, and often available in abundance. An example is the numbers that a digital water level gauge sends to a computer.
- *Information* is similar to data, but it has a meaning. It is processed, and therefore easier to read for most users. Information is quantifiable by counting the number of information fields. An example is the water level of the river. This is calculated by transforming the measured water level, in combination with the relative elevation of location where it was measured, into a water level in relation to the NAP. In general, multiple sources of data are needed to generate information.
- *Knowledge* is a personal (and therefore, subjective) interpretation of information. It has a meaning for the information absorber who understands the information. Moreover, knowledge is not quantifiable, since it is simply located in an individual’s brain. Knowledge can be gained by absorbing and understanding different sources of information. An example of knowledge is when a person knows how high a river’s water level can normally rise before overflowing the dike, along with the current water level and the circumstances that will influence the situation in the coming hours. In combination, all these aspects can render a person capable of making decisions about measures aimed at reducing the impact of a possible flood. A brief overview of the main differences between the first three aspects is given in Table 2.2
- *Action* is an activity that takes place after knowledge is gained. One example is the decisions that planners must make during the spatial planning process. However, action can also describe the activities that are performed after a decision (e.g. building a new neighbourhood). In this thesis, action means making a decision. A concrete example is the choice to enforce the dike or not building any houses behind it, since the risk is too high.
- The *result* is the situation after the action has been performed. If the ‘action’ is interpreted as decision, the result is a selected alternative, which is incorporated into spatial plans. If the ‘action’ is interpreted as building something, the result will be the implemented alternative. This research has used the first approach.

Table 2.2: Main differences between data, information, and knowledge

Data	Information	Knowledge
is objective	is objective	is subjective
has no meaning	has a meaning	has a meaning for a specific person
is unprocessed	is processed	is processed and understood
is quantifiable	is quantifiable	is not quantifiable, there is no knowledge overload

Interwoven among data, information, knowledge, action, and results are certain sub-processes where the knowledge management can go wrong in different ways. De Vos (2009) called these processes gaps. This thesis focuses on the gap between information and knowledge. Murray (2000) made an interesting distinction between explicit knowledge (i.e., ‘knowledge as a body’) on the data side of the process, and implicit knowledge (i.e., ‘knowhow’) on the action side of the process. Since the goal of this chapter is to find the information that should be presented by the Explorer, the focus is on knowledge as a body (the information side of the expertise gap; see Figure 2.2). It is during that stage of the higher knowledge management process that an instrument should present understandable information, giving users the opportunity to translate information into the knowledge needed to make an appropriate decision.

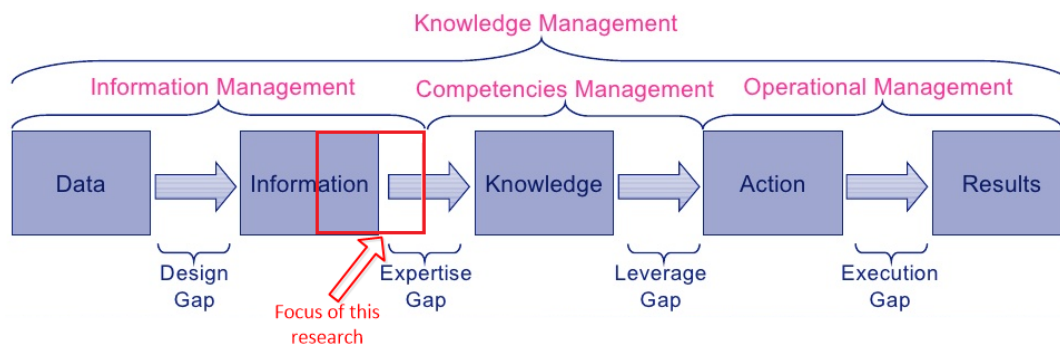


Figure 2.2: Overview of different management gaps that can occur in the DIKAR stream (figure from a presentation by Kees de Vos [2009]).

An essential difference between knowledge and information is that while knowledge is possessed by a particular person with a thorough understanding of the related information, the information can be stored in many locations, e.g. a report or a website. Gaining the right knowledge, which requires understanding the required information, makes someone (more) capable of making the right decision. To justify a decision, individuals can present the sources of information that they used to gain their knowledge. However, a decision-maker cannot always fully explain or write down his or her knowledge, and knowledge falling into that category is called *tacit knowledge* (Hey, 2004). Information can be shared in many ways, but knowledge is more difficult to communicate.

Concrete example of the difference between information and knowledge

This example illustrates the difference between information and knowledge. In 2014, dike-ring 10 was analysed, and the report presented a 1/210 annual probability of flooding (Havinga, 2014). During a flood, the water level would depend upon the origin of the flood and the location in the polder (see 'list of specialist terms'). The maximum depth was predicted to be 5-6 metres at a low lying area named Koekoekspolder in the northwest of the polder. For the remaining parts of the polder, the report estimated water depths between 2.5-4 metres (websites such as overstroomik.nl and the [MLS Explorer](#) give different numbers depending on a several assumptions). The number of casualties was estimated to range between 12 and 215 persons, while the financial damage in case of a flood was estimated at between 210 million euros and 2 billion euros. To gain knowledge about the flood risk and make an appropriate decision, an individual must combine multiple sources of information and understand these figures. A complexity in understanding the probability is already given with the norm of 1/210 per year. This is the probability of a flood occurring due to a number of potential causes. Previously, that probability was primarily calculated on the likelihood of overtopping, but nowadays the specialists have more knowledge about the potential failure systems and therefore the norms have been improved (since 01-01-2017). If one does not know what is meant by 1/210, it will be difficult to make a reasonable decision.

2.3.3. FROM ANALYSIS WITH MODELS TO DESIGN REQUIREMENTS FOR AN INSTRUMENT

From the analysis of the answers to both the interview questions and the sub questions, which were analysed using the two models, a list of preliminary conclusions was drawn. After structuring these conclusions, the main results could be summarised into one programme of requirements, which can be used to assess the quality of an instrument like the MLS Explorer and based on that assessment give suggestions for improvement. In the end of the research these requirements were verified in an interview with Durk Riedstra (2016), who works for the organisation that commissioned the design of the instrument.

3

BACKGROUND INFORMATION

Before the real content of the conducted research can be explained, it is important to give a more elaborated insight into three topics that are essential to understand the whole research. This starts in the first section with the cognitive differences between the disciplines of spatial planning and flood risk management. Both realms frame their problems and potential solutions in a different manner. After this is explained, the Multi-Level Safety concept will be explained more substantive than in the introduction. The last section of this chapter explains the origin of the MLS Explorer, which is the instrument that has been the main subject of this research.

3.1. DIFFERENCES BETWEEN SPATIAL PLANNERS AND FLOOD-RISK MANAGERS

There is a substantial difference between spatial planners and flood-risk managers.¹ This topic is relevant, since the MLS Explorer was designed to (partially) close the gap between these two realms. Flood-risk management and spatial planning are both disciplines that have a long history in the Netherlands. The cultural differences can be found in the fact that flood-risk management is (or was) mainly a technical realm concerned with calculating the required strength and height of dikes, and the results were used to design in accordance with established safety margins (Hidding & van der Vlist, 2009, p.115). Other aspects (e.g. nature, appearance, and the potential for other developments) were not included as design criteria. Spatial planners, on the other hand, were active in a more social realm and needed to consider numerous criteria before making decisions. This same cultural difference was found in the urban water management, where the municipality is a mix of variable disciplines and visions that looks for strategic solutions and is people oriented. This whilst the water board has the engineering culture that is environment and water oriented Therefore it has a smaller scope for solutions. Developments in recent decade have pointed to the need for better cooperation (Correljé & Broekhans, 2014; Wiering & Immink, 2006; Woltjer & Al, 2007). The differences between both disciplines are structured side by side in Table 3.1.

Table 3.1: Differences between flood-risk management and spatial planning, based on de Graaff et al. (2009), de Bruijn et al. (2010) and Hidding & van der Vlist (2009).

Flood-risk management	Spatial planning
Technical	Social
Technocratic decisions	Democratic decisions
Only a few stakeholders	Many stakeholders(integration needed)
Static	Dynamic
Project management	Process management
Best alternative calculated objectively	Best alternative determined subjectively
Government (slowly moving towards governance)	Governance

In the differences between flood-risk managers and spatial planners The gap between these realms started to shrink around 1970. From that time onwards, a slow paradigm shift began to occur, resulting in a tendency to-

¹In this thesis the main focus is on flood-risk management. This can sometimes be confused with water management, but flood-risk management is seen as a smaller discipline within the realm of water management. This is explicit focusing on one aspect is also one of the main differences between water managers an spatial planners, the planners are more broadly oriented whilst water managers often tend to focus on one technical subject

wards better cooperation (Correljé & Broekhans, 2014; Wiering & Immink, 2006). During this rapprochement of spatial planners and water managers, public resistance to building strong dikes and ‘simply keeping the water out’ started to grow. Until 1995, opposition to building higher and stronger dikes was growing. After the near-floods of 1993 and 1995, this discussion was ‘settled’ due to the immediate need for dike reinforcement. However, these revisions were undertaken with the promise that the reinforcements would be temporary, with new solutions to be ultimately implemented. The changes in flood-risk management emerged in politics via the adaptation of the Delta Plan in 1974. From that year onwards, that plan sought to achieve multiple goals beyond flood protection (Correljé & Broekhans, 2014).

This cooperation started to gain more support in the beginning of the 21st century when a report by the Water management committee for the twenty-first century (Commissie Waterbeheer 21e eeuw, 2000) mentioned that water management and spatial planning should be more closely aligned. A Rijkswaterstaat (2005) report further explained that a new method should be adopted and suggested a risk-based method estimating the probability, potential victims, and potential damage. The goal was to use those results to be able to make the best decisions about measures for reducing the flood risk. This method was not new, as Van Dantzig (1956, p. 279) already mentioned that, ‘*The economic decision problem can be formulated as follows: Taking account of the costs of dike building, of the material losses when a dike break occurs, and of the frequency distribution of different sea levels, determine the optimal height of the dikes*’. However, at that time, experts lacked insight into potential losses due to a lack of available data. At present, more information is available, but the number of people able to interpret it remains quite low. This risk-based method formed a foundation for new developments. Examples include flood-risk maps, which are publically available on the risk map website [risicokaart], and the MLS introduced by the National Water Plan [Nationaal waterplan] (Min. van V & W, 2009).

Thus, methods for coping with flood risks have changed in recent decades. First, there was a shift from considering the probability of exceedance towards considering the probability of flooding. The first policy only takes into account high-water situations, while the second looks at multiple failure mechanisms that can cause a flood. This new perspective resulted in new flood-risk norms that became effective as of 1 January 2017. The next step is considering the flood risk instead of only the probability, which means also taking into the potential impact of such an event. This new approach creates more room for new measures. Reducing the likelihood of a flood can mainly be achieved by building higher and stronger dikes, or by creating more space for water. In contrast, risk-reducing measures can take a range of actions. These new approaches create a demand for specific information, such as the spatial value of the area behind a dike or the soil type under a dike, which is needed to quantify or map the risks (Rijkswaterstaat, 2005).

One of the changes that stimulated cooperation between spatial planners and flood-risk managers is the water test. In the year 2000, the Tielerooij committee recommended that a water test should be used to assess how spatial planning decisions affect the water system (Commissie Waterbeheer 21e eeuw, 2000). This water test was introduced in 2001 and became effective in 2003 (Wagemaker, 2003). It consists of a process instrument that sets rules concerning the role of water-related variables in spatial planning decisions. A more in-depth overview of changes in water management and spatial planning can be found in appendix A. The main similarity between water management and spatial planning is that both change the spaces in which we live to meet their goals. However, the ways in which they perform this task differs significantly.

3.2. MULTI-LEVEL SAFETY

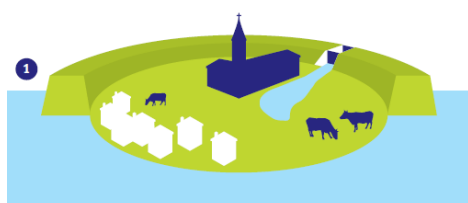
It is slowly becoming clear that the climate is truly changing. The effects appear in different forms. The best known examples are extreme weather events, such as intensive rainfall and droughts, and melting ice in the Arctic. For a low-lying country such as the Netherlands, the result has been an increasing flood risk due to multiple factors: rising sea level, the higher level of river discharge with dangerous peaks, and intense rainfall that result in a more local flood risk (e.g. several streets). Dutch politicians already responded with several new measures, like more room for the rivers [ruimte voor de rivieren] and the Delta programme [Deltaprogramma] (for a comprehensive chronological overview of political events related to flood-risk management, see appendix A). Thus, there is already political awareness within the government.

The approach of reducing flood risk has changed in the last decades. The main difference concerns the def-

inition of ‘risk’. Quite often the words ‘risk’ and ‘probability’ are used interchangeably, even though they significantly differ in meaning. *Risk* is the product of *probability* and *potential consequences* (Samuels & Gouldby, 2009). Therefore *flood risk* is a combination of the probability of a flood occurring and the potential impact that such an event would cause. As a result, the flood risk can be minimised in various manners, such as reducing the probability of such an occurrence and/or by mitigating the potential consequences, which can be achieved by means of spatial planning.

The Dutch government has repeatedly recognised the need for better cooperation between flood-risk managers and spatial planners, but improving this cooperation seems to be quite difficult. The need better cooperation was recognised at the beginning of the new millennium, when the Dutch government stated that water policy changes would be necessary to keep the country safe, liveable, and attractive (Min. van V & W, 2000). The National Water Plan that was written in 2008 [Nationaal Waterplan 2009-2015] it was described that; ‘*water should be more determinative when deciding on major challenges in the field of urbanisation, business and industry, agriculture, nature, landscape and recreation*’ (Min. van V & W, 2009, p. 5; An extensive overview of the political moments can be found in appendix A).

One of the political initiatives was the introduction of Multi Level Safety in the National water plan for the period between 2009 and 2015, that was presented in the end of 2008 (Min. van V & W, 2009). In this document the Cabinet has opted for a sustainable flood risks policy by using three different levels of protection (i.e., prevention, sustainable spatial planning, and disaster management). These levels contain a variety of measures that help to reduce the flood risk in different ways. The visuals contained in Figure 3.1 are often used to explain the differences among the three levels.



The first level is prevention, and it concentrates on reducing the probability that a flood will occur. For a long time, this was almost the only way of managing the flood risk. The government has explicitly mentioned that prevention will remain the most important level in the Dutch flood-risk policy (Min. van V & W, 2009), Although it will also pay attention to the other levels.

The second level aims to lower the (financial) damage in case a flood actually occurs. This can be managed by developing areas so that essential buildings and infrastructure are built in locations that are not easily reached by water. For example, elevated building sites and (natural/artificial) barriers surrounding the area are means of mitigating damage. This sustainable spatial development, which can withstand flooding to a certain extent, is quite difficult to achieve, because it requires long-term measures, which are associated with both high costs and uncertainties.

The third level focuses on the preparedness of people who are affected by flooding. Concrete examples include informing people about their risk and explaining how they can prepare for possible floods (e.g. how and where to flee). In addition, training for aid organisations is part of this level. These measures focus on reducing the number of casualties.

Figure 3.1: Visualisation of the three levels of Multi-Level Safety (adjusted figure from (Pötz et al., 2014, p. 6))

The MLS concept can be explained by means of the ‘risk’ definition. This risk can be split into three components: probability, exposure, and vulnerability. These three aspects all contribute to the overall flood risk (Klijn, Kreibich, & De Moel, 2015). When one single component is reduced, the overarching risk simultaneously declines. Up until the second half of the twentieth century, the Dutch approach mainly focused on

reducing the likelihood of a flood, but that policy has broadened to include a wider search for more cost-effective measures that preserve the landscape while also reducing exposure or vulnerability.

With the goal of experimenting and learning how to implement this new approach, multiple pilot projects have taken place throughout the whole country. A comprehensive overview is given on a website by STOWA (www.meerlaagsveiligheid.nu) mapping many MLS projects and providing links to reports and short films on the topic (STOWA, Rijkswaterstaat, & HKV, 2014). These studies have resulted in increased understanding of how the MLS strategy can be effectively carried out. (Min. van I & M, 2015; Oranjewoud & HKV lijn in water, 2011; van Buuren, Ellen, van Leeuwen, & van Popering-Verkerk, 2015). Some MLS evaluations have concluded that MLS is not yet sufficiently developed. 'Deltafact',² which was compiled in 2013 and updated in 2016, identified several important knowledge gaps (STOWA, 2016). For example, it identified uncertainty in flood prediction models and a lack of testable norms for levels 2 and 3. This makes it hard to enforce the implementation of measures from these levels. Other studies have considered instruments aimed at offering insight into potentially interesting MLS measures (Deltares & HKV, 2012). Based on these analyses, new instruments have been developed, including the MLS explorer.

Europe

The European Flood Directive (European Parliament & The Council, 2007) describes the risk approach as a cyclic management process. This process contains five aspects: (1) high water protection, (2) damage prevention, (3) preparedness, (4) emergency measures and (5) recovery measures. In all of these areas, different measures can be taken to reduce the flood risk (Raden voor de leefomgeving en infrastructuur, 2011)

The European Flood Directive compelled national governments to conduct flood-risk assessments and to develop flood hazard maps, flood-risk maps, and flood-risk management plans (European Parliament & The Council, 2007). In 2009 a new means of accounting for the flood risk in the spatial planning was introduced by the Dutch government: the use of flood-risk zoning. This way areas with different risks can be distinguished and get can different zoning rules (Pieterse, Knoop, Nabielek, & Tennekes, 2009). The report concluded that the new flood-risk zoning approach emphasises mitigating the consequences, rather than only reducing the probability.

During this research the researcher identified that during the process of developing new spatial plans, planners use numerous criteria to make decisions, but in many cases, none of those criteria are related to the flood risk. This fact is rather unusual for a country in which 60% of the land is prone to flooding. Given that context, in most places, the flood risk should be reflected in at least one criterion in the choice for a location or design of new plan.

3.3. THE MULTI-LEVEL SAFETY EXPLORER

The following section provides an elaborate explanation of the MLS explorer, including how it was developed, how it works, and what information it can provide.

The MLS explorer is a website ([weblink](#)) that has been online since October 2014. It offers initial insight into the local flood risk and the possible effects of new developments. In short, it is an online instrument that spatial planners can use to map foreseen developments and obtain information about the related flood risk that comes along with the chosen spatial development. The Directorate General for Public Works and Water Management (DGPWWM, [RWS]) commissioned this instrument, and its development was jointly executed by Deltares and HKV. The initially foreseen users were policy officials representing municipalities, provinces, safety regions, water boards and the national government. The Explorer provides information related to the following aspects (Bouwer, van der Doef, & Slager, 2014):

- Type of flood risk
- Maximum water depth and probability of flooding
- Consequences of flooding in terms of damage and casualties
- Probability of the success of different kind of measures
- Approximate indication of costs and benefits

²This is an online knowledge dossier aimed at ensuring that the latest knowledge on climate and water management is spread.

An important note regarding the Explorer is that it only gives the user a first glimpse of the local flood risk and the potential added value of detailed MLS studies for that specific location. Furthermore the instrument is specifically meant for choice of a location and the decisions related to the design, both the execution method (building on higher ground) and construction method (building flood-proof) (Bouwer et al., 2014).

The current MLS Explorer can be seen as the ‘little brother’ of the MLS Tool, an instrument that flood-risk specialists employ to calculate the site-specific flood risk and the costs and benefits of potential measures. This MLS Tool can be used to make detailed calculations, and it has the flexibility to experiment with many assumptions. This flexibility is simultaneously the main downside of the tool, since that aspect goes hand in hand with complexity. According to D. Wagenaar (external supervisor), there are only few experts (≈ 20) in the Netherlands able to work with this tool. Thus, if a municipality wants to know the flood risk for a specific location, it first needs to hire an expert. This requirement creates a barrier when it comes to assessing the flood risk prior to a spatial development. To address this obstacle, the ‘little brother’ was developed. The MLS Explorer is free to use, has a simple user interface, and is accessible via the internet (i.e., no software needed). The quick-scan instrument primarily aims to provide insight into the flood risk related to new spatial developments. Secondly, it offers an initial evaluation of the effects of several measures intended to reduce the flood risk. This information can help planners decide whether to change locations or conduct more detailed research on interesting MLS measures.

In developing an instrument like the MLS Explorer, it is essential to understand the difference between two separate approaches to MLS. These two approaches each have their own objectives, and the MLS Explorer is mainly suitable for one of them. One method seeks to achieve the flood-risk norms with smart combinations of different measures, and the second seeks to develop an area flood resistance such that the potential impact remains low or even declines. This last method is independent from the Dutch flood risk norms, it is done on top of the measures that are needed to reach the norm. Table 3.2 gives a better insight into the main differences between these approaches. The chosen approach determines the information needed to make decisions.

Table 3.2: Two approaches to MLS, taken from presentation by David van Zelm van Eldik about MLS (STOWA, 2014)

Smart combination to achieve a norm	Robust development to reduce potential impact
Smart combinations	Water robust development
Basic safety for everyone	Impact reduction for vital and vulnerable functions
New water safety policy	Complement to spatial planning policy
Starting point is water safety task	Starting point is spatial task
Steering on solving of bottlenecks	Steering on opportunities in the area
Periodic evaluation and new norms	Continuous search for area development
Central safeguarding of measures by law	Decentralised implementation
Focused on primary water system	Focused on primary and regional water system
Financial coverage by Delta Fund	Financial coverage from land exploitation and replacement investments
Inside the dike	Inside and outside the dike
Water and spatial planning actors on dike-ring level	Spatial planning actors on local/regional level

The researcher of has the opinion that the MLS Explorer is mainly (if not only) suitable for the second approach (right side of the table), because Dutch flood-risk norms are designed with cost-effectiveness as one of the criteria, meaning that measures from the second or third level are almost never deemed financially viable options for protecting a site. Therefore, second- and third-level measures are unlikely to score highly in comparison with measures that target to simply compliance with norms.

For the first approach, the MLS Tool is the more suitable option. Analyses associated with that approach are typically performed by flood-risk specialists who make more specific calculations. Another reason why the second approach has more potential for the MLS Explorer is that local developers are the ones who must determine if they are willing and able to implement more flood-resistant designs. For investigations, the Explorer can be used to experiment.

DETAILED PROCESS DESCRIPTION OF THE MLS EXPLORER

The current MLS Explorer contains six main steps, which fall into two categories: (1) steps that users must perform and (2) steps in which the system presents results via internal calculations. Figure 3.4 shows a

scheme that was made with Integration Definition modelling language IDEF0³. This figure visualises the whole process that will be described first. The description is given by the author of this report and not from the designers of the MLS Explorer. A visual overview with screenshots is located in appendix C and Figure 3.2 contains a link to a short online video explaining how the Explorer works for a specific area in the Netherlands.

Introduction After entering the website address (www.mlverkenner.nl), the Explorer starts with a welcome screen that outlines its purpose. Users then select 'start the MLS Explorer', and six steps appear on the left-hand side of the map. These are: (1) choose your area, (2) view your area, (3) choose your development, (4) show risk in the area, (5) show effects of possible measures in the chosen area, and (6) assessment framework.

Step 1: Choose your area. In this step, the user sees a map of the Netherlands. Users can zoom in on the area considered for development and subsequently draw the borders of that zone on the map. Then, the user can click the 'next' button, and the system calculates the specific risk for that area.

Step 2: View your area. Next, the system⁴ performs calculations and presents information. First, a numeric table presents the potential water depth, the current probability of flooding, and the probability of flooding after the new norms have been realised. These values are given for three types of land: behind primary flood defences, behind regional flood defences, and outside the dikes. The system can display figures for all three categories into which the delineated area falls. Moreover, the system indicates size of the area in hectares. After the user clicks on 'go further', a map with the maximum water depth and the earlier drawn area borders appears. The user can also switch between maps with elevation and a map with the expected water depth. On both maps, the user can click on specific points to see the specific values associated with them.

Step 3: Choose your development. In this step, the users selects of five possible types of development (i.e., single family houses, apartment blocks, office buildings or shops, industry, or public utilities [e.g. electricity transformer houses or telephone transmission towers]). Each alternative rests on unique assumptions regarding the number of persons likely to be present, the number of units able to be built per hectare, and the new value of the location. After the users clicks the 'next' button, the system calculates the consequences, which are illustrated in the fourth step.

Step 4: Show risk in the area. The fourth step offers a considerable amount of information in four stages: First, the user sees the number of fatal casualties and the financial damage that a flood would likely cause. Secondly, the expected annual financial damage and number of fatalities are presented for both the current situation and a scenario in which the new norms have been realised. This is comparable with the first step, but then multiplied with the chance. Thirdly the system illustrates for both scenarios (current/new norms) the present value of the expected damage. Fourthly, the system offers maps indicating the local individual risk [Lokaal Individueel Risico (LIR)] and the local damage threat [Lokaal Schade gevaar (LSG)]. For a further explanation of these terms, see the list of Dutch names in the Glossary at the beginning of this report.

Step 5: Show effects of potential measures in the chosen area. The fifth step illustrates the effects of different measures on several risk variables in the delineated area. These measures are divided in two categories, the first reduces financial damage and the second reduces the number of victims. The first category contains four measures: wet-proof building,⁵ dry-proof building,⁶ integral soil raising with one metre, and integral soil raising with two metres. The second category, aimed at reducing the number of victims, contains three possibilities: integral soil raising with one metre, integral soil raising with two metres, and taking measures that improve the expected evacuation rate.

The measures in both categories are calculated for both situations with the current and new norms. This results in 14 ($3 \times 2 + 4 \times 2$) scenarios. For all these scenarios, the estimations are provided for both categories. For the first category (damage reduction), estimates are provided regarding the cost of the measure, expected benefits, and the benefit/cost ratio. For the second category (reduce the number of victims), the following forecasted figures are provided: the expected costs of the measure; the expected number of victims without the measure; the expected number of victims with the measure; and the difference between these last two



Figure 3.2: A QR code with a [link](#) to a short movie explaining how the Explorer works.

³The term IDEF stands for **I**ntegration **D**EFinition, which is a modelling language that can be used to model processes. It was initially developed in Europe under the name Structured Analysis and Design Technique (SADT), but it was later standardised under the name IDEF0 [NIS93]. The IDEF modelling family contains multiple versions (i.e., IDEF0 through IDEF14). The IDEF0 methodology offers a functional modelling language for the analysis of information systems.

⁴The system has several map layers with data that are used to perform the calculations on which the presented information is based

⁵Wet-proof building means that the water can enter the building but furniture and contents located on the ground floor is water resistant

⁶Dry-proof building means that water cannot enter the building

figures, which represents the benefits conferred by that option. This fifth step gives the most information by means of 48 numbers ($4x3 + 3x4 + 4x3 + 3x4$).

Step 6: Assessment framework. Finally, key information is summarised in a table containing all of the measures and the reference situation (status quo). This table can be given for both current situation and the situation with new norms.

To provide a clear overview of the MLS Explorer, the whole process is visualised by means of the Integrated Definition modelling language (IDEF0) in figure 3.4. The legend in Figure 3.3 explains how the IDEF0 should be read. The square boxes indicate a process or action that the user or the system can perform. This steering is indicated by the arrow running towards the box from above. For ease of interpretation, all activities that are directed by the system are in purple, and those actions that are directed by the users are in green. Every action transforms information into new information that the Explorer presents, as illustrated by the orange box with the 'info for user' arrow. That information is simultaneously an output and an input for the next step, which might consist of the user adding information or of the system simply performing a new calculation. Every process is supported by the system, and the system actions rely on the database and map layers to calculate the outcomes.

An important conclusion that can be drawn from this section is that the Explorer only allows users to provide input at two moments. The remainder of the process simply consists of clicking the 'next' button and observing information provided by the Explorer. The Explorer estimates the costs of the various measures, as well as the potential damage. Of note is that the maintenance of suggested measures is not taken into account in these calculations.

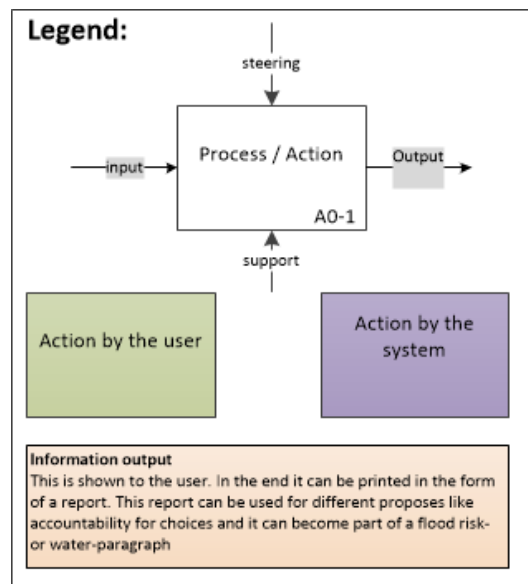


Figure 3.3: Legend that belongs to figure 3.4

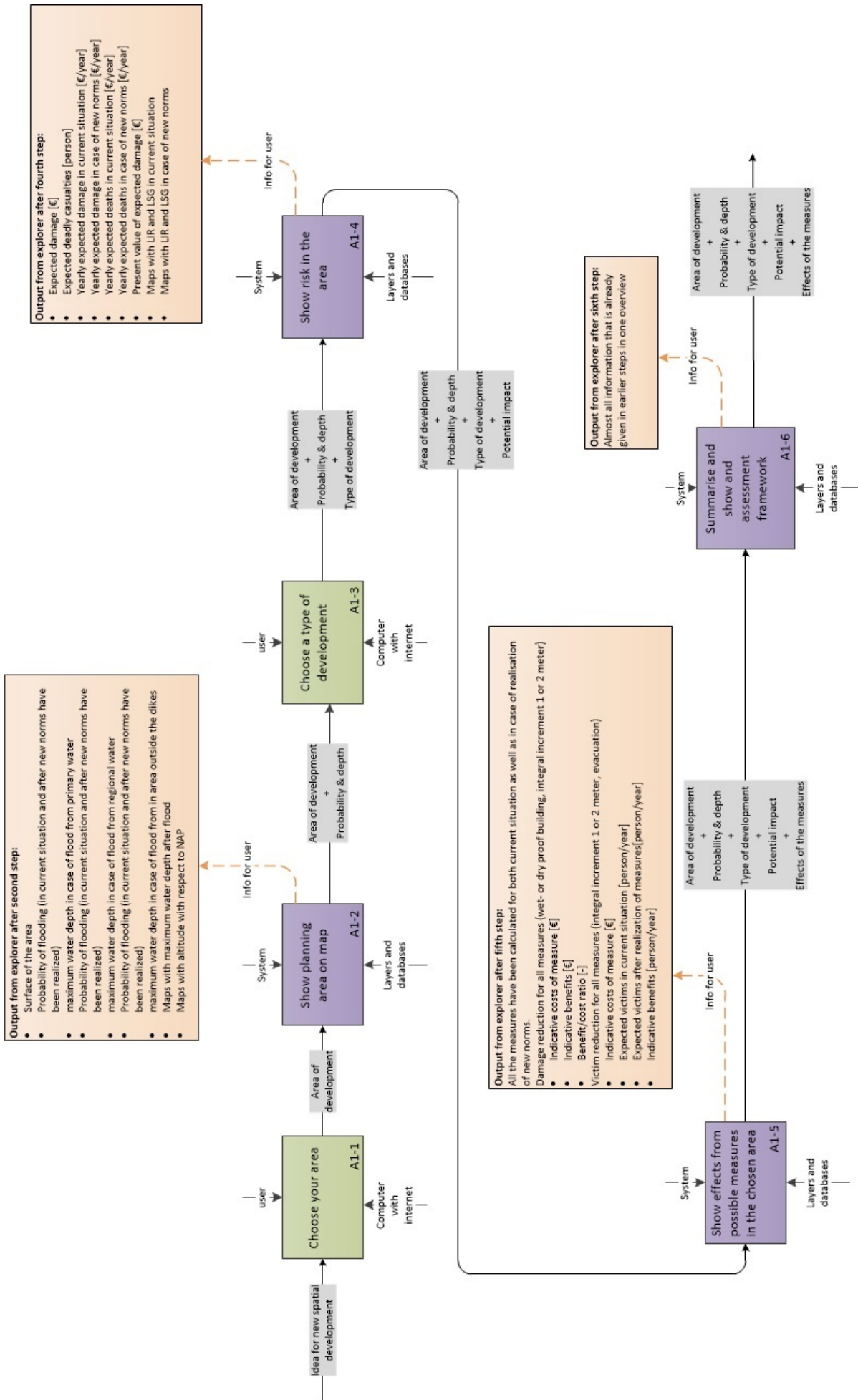


Figure 3.4: IDEFO scheme with all steps of the current MLS Explorer.

4

INTRODUCTION OF FOUR CASES WITHIN TWO REGIONS

The following three chapters focus on the case studies. These cases were analysed to answer the first four research questions.

1. When should the flood risk be assessed during the spatial planning process?
2. Who are best suited for conducting an exploratory flood-risk assessment?
3. What information should the instrument present?
4. How should the information be presented?

Two models were used to answer these questions. In chapter 5, a spatial planning model is employed to distinguish individual phases within the larger planning process and the players involved during each stage. In chapter 6, the RAKID model is used to determine what information was used and how it was presented. Both models are employed to the four cases, two in the IJssel-Vecht region and two in the Venlo region (see Figure 4.1). The characteristics of the areas and cases within these areas will be explained in the following paragraphs.

4.1. FIRST REGION: THE IJSSSEL-VECHT DELTA

The first region was the IJssel-Vecht Delta. This area encloses the city of Zwolle and continues towards the West until the Ketelmeer (see Figure 4.2). On its southern side, it borders the river IJssel, while it borders the river Vecht in the north. The Vecht continues through the river Zwarte Water and subsequently ends up in the lake Zwarte meer. All the waterways eventually end in Lake IJssel [IJsselmeer].

The last serious flooding in this area was in 1825, when a large part of the delta, including the city of Zwolle, was flooded, and 305 people died (Canon van Overijssel, 2016). After this flood, several measures were taken to prevent a repetition. Nevertheless, during a storm in 1916, a large part of Kampen and the outer-dike area, located between dike-ring 10 and the Zwarte meer, was flooded. The inside of dike-ring 10 appeared to have been sufficiently reinforced after the flood of 1825. After the storm of 1916, which caused more damage in other parts of the Netherlands, a closure dam [Afsluitdijk] (see Figure 4.1) was built to prevent such flooding from happening again. Despite these measures, risky situations still arise when a north-western storm pushes the water from Lake IJssel via the Ketelmeer up towards the IJssel-vecht Delta. Therefore, an inflatable dam (Ramspol barrier) was built in 2002. This barrier protects the IJssel-Vecht Delta when the water level in the Ketelmeer exceeds 0.5 metres above NAP.¹

Until so far, this section has addressed the flood risk from the western side, but in this area, rivers to the east also pose a threat. Serious high-water levels in 1993, 1994, 1995, and 1998 (and especially in 1993 and 1995), mainly caused by heavy rainfall in the larger river area, have led to more political consciousness (Commissie Waterbeheer 21e eeuw, 2000).

¹Normaal Amsterdams Peil, this is a standardised measure of the approximate average sea level that is used as a zero point for elevation measurements.

This awareness has resulted in plans to increase the discharge capacity, which are currently being developed and implemented. For example, the Reevediep project consists of an extra discharge canal from the IJssel towards Drontenmeer.

The IJssel-Vecht Delta was included in this study due to an extension area (Stadshagen) just outside the City of Zwolle (in Figure 4.2, the smaller circle to the west of Zwolle). Interestingly, this area is situated in a different dike-ring than the City of Zwolle. To better understand the context, a brief chronological overview of spatial planning will be given. The time frame of interest in the first region spans from 1990 until 2017, and within that period, three separate time periods are identifiable. From 1990 until 2000, Dutch spatial planning, after the recovery from the crisis of 1987, was predominantly implemented in a top-down manner to cope with the rapidly rising demand for housing. Secondly, between 2000 and 2010, the housing market slowly stabilised until it collapsed in 2008. During the housing crisis, hardly any new projects started; only projects already under construction were finished. Third, from 2010 until 2017, new exploratory activities concerning spatial development in Stadshagen gradually started to take place. The two cases that were analysed took place within the first and third frame.

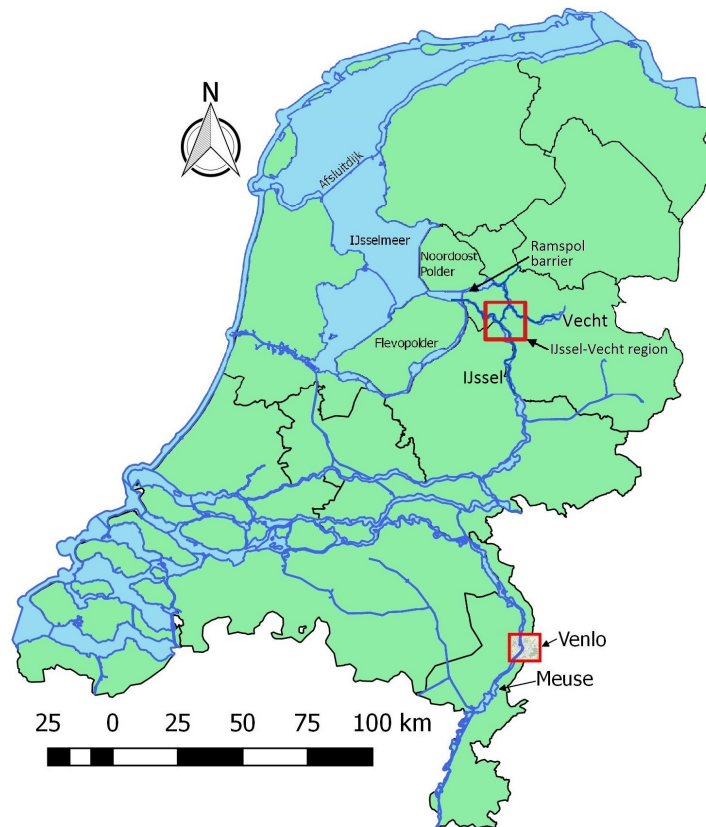


Figure 4.1: Location of both the cases in the Netherlands, with the IJssel and Vecht in the northern part and going around Zwolle and the Meuse River splitting the municipality of Venlo.

The first case concerns the choice of a location for an Expansion of Zwolle, which eventually got the name of ‘Stadshagen’. This decision concerned the city of Zwolle, which had to expand between 1990 and 2010 with 12,100 houses, a figure equal to approximately 30% of the existing housing stock (37,500 in 1990). The city itself was not large enough to accommodate all of the growth.

The second case is about a choice between different alternatives of a flood-retaining sound barrier around Stadshagen. The period of interest was approximately 2010 until 2017, wherein governments started to plan new spatial developments. Both cases are explained in more detail in chapters 5 and 6, which apply specific models to them.

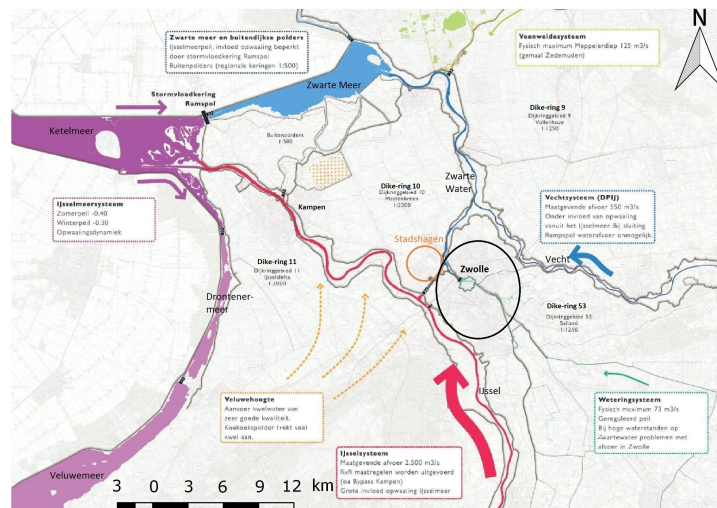


Figure 4.2: Several water bodies and dike-rings located in the IJssel-Vecht region (H+N+S Landschapsarchitecten et al., 2013, p. 36)

4.2. SECOND REGION: MEUSE AT VENLO

The second region is situated in the south-east of the Netherlands (see Figure 4.1), and it differs in multiple aspects from the first region. It only contains one water body (i.e., the Meuse River); there is a lower demand for housing; and the landscape features more elevation differences, which can serve as natural flood barriers. This region is around the city of Venlo, which is traversed by the Meuse River (see Figure 4.3). This river has a large variation between high and low water levels, because its riverbed is quite small compared to other rivers that enter the Netherlands. Due to this small size, heavy rainfall in the Belgian Ardennes can cause significant water-level increases within a single day (Infram, CSO and HydroLogic, 2011, p. 120). The river seemed to be well tamed until 1993. In that year, high water levels demonstrated that extreme weather could still cause problems (Commissie Watersnood Maas (Boertien II), 1994). The water level around Venlo is, on average, 11.6 metres above NAP (Rijkswaterstaat, 2016), but in extreme situations, such as those in 1993 and 1995, that level can be as high as 18.46 metres above NAP (Goudriaan, 1995, p. 18 of the appendix).

The minimum ground level in the Meuse is around 11 metres above NAP, but it quickly rises to 25 metres above NAP. Two kilometres further the ground level is 40 metres above NAP. The behaviour of this river is difficult to predict, since sufficiently detailed data for flood-safety modelling is not available (Infram, CSO and HydroLogic, 2011, p. 16). This makes it challenging to identify promising MLS measures. Until the floods of 1993 and 1995, Venlo had no primary dike to protect the city against flooding. Therefore, the experience with dikes and flood protection were almost non-existent as compared to the IJssel-Vecht region and other areas in the Netherlands.

These events resulted in significant political pressure to change flood-risk management practices around the Meuse, and they encouraged a high level of public acceptance of rapid dike construction (van Hal, 2016, Personal interview). In 1996 the water boards in Limburg and RWS constructed (temporary) dikes under the Delta Act Large Rivers [Deltawet grote rivieren] (Rijksoverheid, 1995). The frequency norm for those dikes was set to a maximum exceedance of 1/50 per year. Before the construction of these dikes, the water was mainly regulated by natural high grounds and only a few quays (Commissie Watersnood Maas (Boertien II), 1994, p. 26). If people wanted to live closer to the river, they did so at their own risk. Since these dikes were temporary, they did not have 'primary dike' status in the First Law on Flood Defence [wet op de waterkering] in 1996.

In 2006, After two test rounds,² the government concluded that the dike-rings along the Meuse in Limburg had to be categorised under that law, however, and so those dikes gained 'primary flood defence' status. This reclassification also meant that the dikes could not be removed, because research had demonstrated that measures intended to reduce the flood risk, such as deepening and widening the river, would not result in sufficient risk reduction.

The Meuse region around Venlo has several dike-rings, while other areas are simply protected by high grounds. Dike-rings 68, 69, and 70 are the three main dike-rings around Venlo (see Figure 4.3). The dike on the east side of the Meuse (68) has an annual probability of being exceeded by a flood of more than 1/100, according to a report from 2014 (de Groot, 2014). All dikes in Limburg have to be designed according to an annual probability of 1/250 that is will be exceeded by the river. However, many of Venlo's inhabitants do not like the

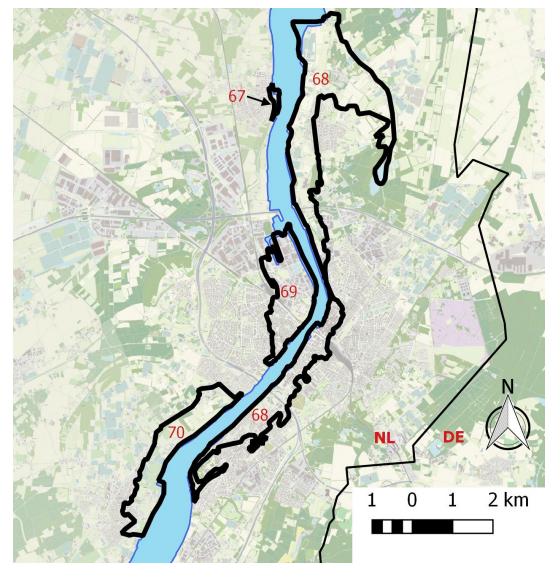


Figure 4.3: Figure with dike-rings around Venlo, nr 68 is quite large compared to the average ring in Limburg but way smaller than other dike-rings in the Netherlands

²The dikes in the Netherlands are tested in a fixed time interval. In the beginning this was every five years, but since the Water law [Waterwet] in 2009 this period frequency changed into once every twelve years.

view from the back of the levee and want to see the river again. This conflict of interests calls for a new way of reducing the flood risk. There is a location called 'Kazerne Kwartier', which was temporarily used as city hall, recently became available for redevelopment. Venlo has taken a positive stance towards potential MLS solutions, and the city has hired a consortium to design a plan eligible for national government funding. In this region again two cases are analysed, both are typical exploratory phases that fit well into the goals of the MLS-explorer.

The third case is an exploratory search for MLS measures in a dike-ring. It can be placed even before the problem identification of the spatial planning process since it searches on potential application of the MLS concept because there are potential problems foreseen. Despite the fact that it is in front of the spatial planning process, the spatial planning model can still be identified.

The fourth case again is an exploratory research. This time a search for new developments in the municipality of Venlo. The municipality uses a procedure that is prescribed by the national government in order to qualify for extra funding. This case is interesting since the analysed national procedure is used by more local governments. If a specific purpose of the MLS Explorer can be appointed, which lead to ideas of how the Explorer can be made more suitable for that purpose.

5

CASES ANALYSIS VIA THE SPATIAL PLANNING MODEL

This chapter uses the six phase of the spatial planning model, explained in chapter 2.3.1, to answer the first and second research question of this research, when should flood risk be assessed? And who are best suited for conducting this assessment?. The results are presented for all four cases. Every case has a similar structure, it starts with a graph in which all the planning documents that were used to draw conclusions are visualised. This graph has two axes, the horizontal axis represents the six phases that were identified in the spatial planning model, and the vertical axis represents four levels of the spatial planning entities, see Figure 5.1. In this way, the graph shows in which phase the documents played a role and on which governmental level the steering party was.

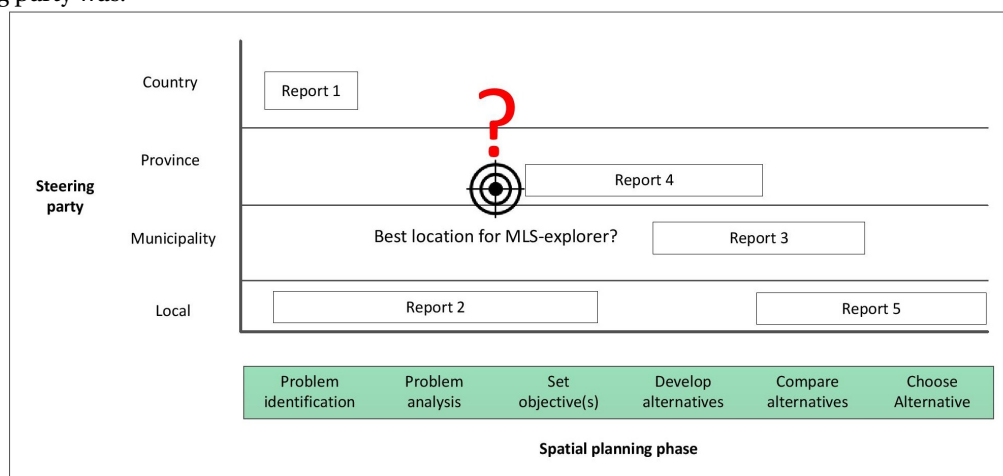


Figure 5.1: This graph demonstrates how the reports analysed in all four cases were organised. The horizontal axis represents the first sub-question, and the vertical axis represents the second sub-question. It gives insight into moments and users with the greatest potential for the MLS Explorer.

After this graph, the real explanation follows with mentioning the most important observations from the planning documents in the sequence of the spatial planning model. Subsequently, the when- and who -questions are answered for that specific case. The results from the interviews are woven into the whole explanation. In the end of the chapter, the main conclusions that yield for all cases will be summarised. These conclusions were used as inputs to create a set of requirements that can be used to assess the current MLS Explorer.

5.1. CASE 1: CHOICE FOR A LOCATION FOR THE EXPANSION OF ZWOLLE

This first case concerns the choice for an area where to expand the City of Zwolle. Planning documents were studied and the most important ones with regard to where the use of the MLS Explorer would have been useful are shown in figure 5.2. The case will be explained in a chronological way, which is quite similar to the horizontal axis.

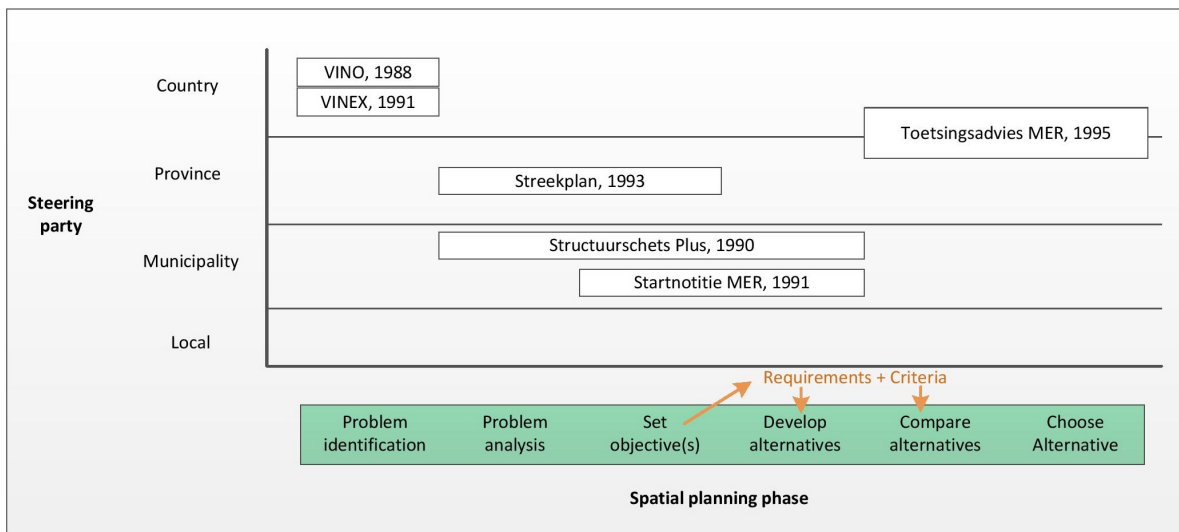


Figure 5.2: Planning levels and phases for the first case. The orange text denotes deviations from the applied spatial planning model. VINO, 1988 = [Min. van VROM \(1988\)](#); VINEX, 1991 = [Min. van VROM \(1991\)](#); Streekplan, 1993 = [Provincie-Overijssel \(1993\)](#); Structuurschets Plus, 1990 = [Gemeente Zwolle \(1990\)](#); Startnotitie MER, 1991 = [Gemeente Zwolle \(1991\)](#); and Toetsingsadvies MER, 1995 = [Commissie voor de milieu-effectrapportage \(1995\)](#)

In terms of scope, this case starts with a growing housing shortage identified in the early 1990s. This identification started on the national level in the structure vision [structuurvisie] named ‘Vierde Nota Ruimtelijke Ordening’ (VINO) ([Min. van VROM, 1988](#)), and its successor ‘Vierde Nota Ruimtelijke Ordening Extra’ (VINEX) ([Min. van VROM, 1991](#)). These visionary documents stated that the housing market had started to grow after the financial crisis¹ and that due to the urgent need for new houses, the government had tried to organise the expansion in a structured way by designating centralised growth locations. One of the objectives for these locations was to minimise the length of residents’ commutes. The quality of economic centres such as the Randstad received the most attention in the central plans. The National government created a list of locations throughout the whole country where municipalities were allowed to expand on a large scale. This list of so-called VINEX locations was assembled in cooperation with local governments. The selected locations were large areas that were selected for the optimisation of public transport. One of these VINEX locations was Stadshagen. The municipality of Zwolle was largely responsible for selecting this location, whereupon the national government included it on the list with VINEX-locations.

Problem identification

As already appears from previous paragraph, the problem analysis was mainly commissioned by the municipality of Zwolle and the province of Overijssel. The study identified population growth between 1980 and 1990 and used a provincial population model to extrapolate further figures. This model predicted that until 2000, the housing demand would count approximately 10,000 dwellings. Since the existing spatial plans only covered just over 5,000 dwellings, the new plan needed to cover approximately 5,000 extra dwellings ([Gemeente Zwolle, 1990](#)). In 1991, a draft of the Structuurschets-Plus² was discussed by the Provincial Commission for Spatial Planning in the presence of an official from the municipality of Zwolle. The outcome was that the municipality of Zwolle needed to identify one or more location(s) with room for 8,500 new dwellings ([Gemeente Zwolle, 1991](#), p. 25). Another 3,000 dwellings were already planned in existing zoning plans. In 1992 a new evaluation was undertaken, and in December 1993, the province of Overijssel’s regional plan [Streekplan] named the desired expansion locations within that region. The plan noted that because of its growing population, Zwolle needed to extend its housing stock by 6,500 dwellings between 1992 and 2000, and a further 5,600 units between 2000 and 2010 ([Provincie-Overijssel, 1993](#)). In sum, this meant 12,100 dwellings before 2010. Compared with the existing number of dwellings in 1990, approximately 37,500 ([CBS Statline, 2016](#)), the expansion was thus quite sizeable.

Problem analysis

As the numbers in the previous paragraph already show, the problem analysis resulted in objectives. These objectives were found on two levels: (1) strong requirements for developing or selecting alternatives and

Set objectives

¹The second oil crisis between 1979 and 1986

²The Structuurschets-Plus was the preliminary draft of the Municipal structuurplan (This document states the objectives that had to be achieved with spatial development for the coming 10 years)

(2) some soft criteria for comparing those alternatives (see ‘develop’ and ‘compare’ on the horizontal axis in Figure 5.2). The Structuurschets-Plus explained that societal and spatial developments had proceeded faster than expected and therefore Zwolle needed to develop new locations for housing and employment (Gemeente Zwolle, 1990). The report stated that the new location needed to be:

1. Situated within the boundaries of Zwolle municipality
2. Situated within a maximum of 4 kilometres from the city centre
3. Chosen upon responsible weighing of values associated with nature and the landscape
4. Characterised by responsible environment protection
5. Comprising a single, compact, new residential district with potential for growth, because of the potential higher rate of return on the investment³

Develop
alternatives

The five requirements, but mainly the first four, were used to select the alternatives, resulting into three possible locations (see Figure 5.3): Stadshagen (with room for more than 8,500 dwellings), Herfte (maximum of 5,600 dwellings), and IJsselfront (maximum of 2,700 dwellings). Only the Stadshagen site was large enough to accommodate 8,500 new dwellings. Therefore the following four alternatives were further compared: (1) Stadshagen 8,500; (2) IJsselfront 2,700 + Herfte 5,800⁴; (3) Stadshagen 5,800 + IJsselfront 2,700; and (4) Stadshagen 5,000⁵ + Herfte 3,500.

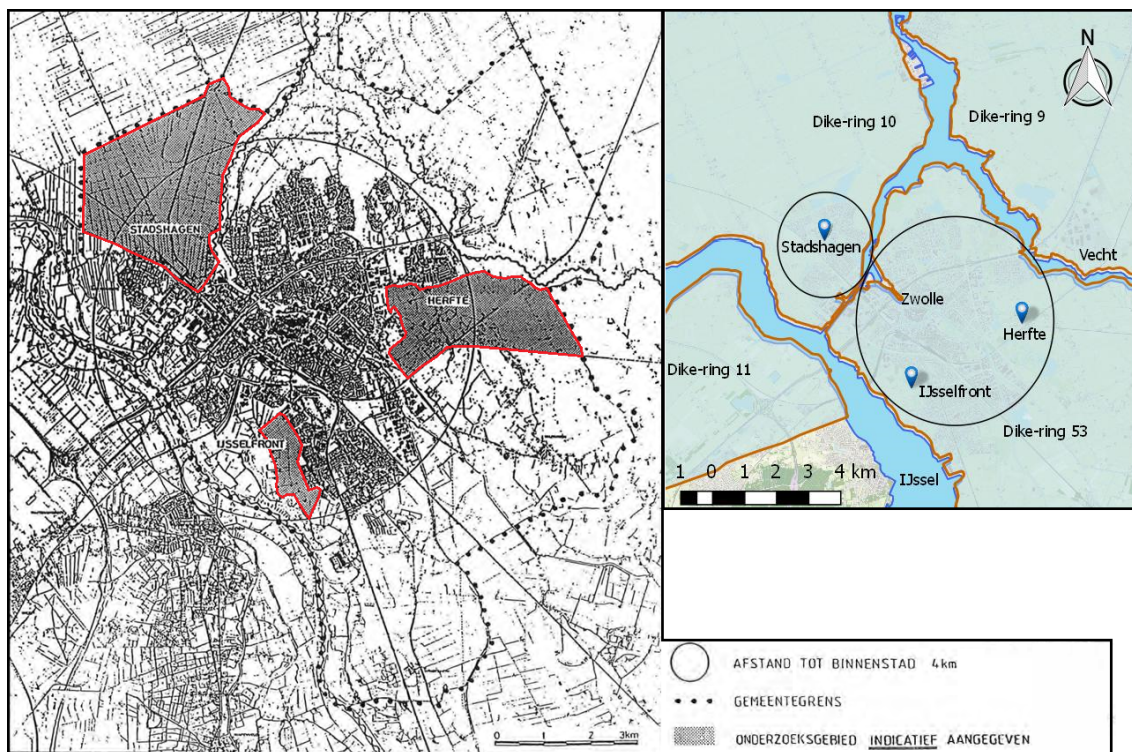


Figure 5.3: Left-hand side, including the legend in the bottom: Map illustrating three locations mentioned in the preliminary memorandum environmental impact assessment (Gemeente Zwolle, 1991, p. 3). Right-hand side: Closer overview of the alternative locations, including the rivers and dike-rings in the area.

Compare
alternatives

The next step was to compare these alternatives. This comparison was based upon a list of criteria, which fell into four categories (the full Dutch list is provided on the left-hand side of Figure 5.4):

1. Spatial aspects [ruimtelijke aspecten]
2. Environmental aspects of spatial changes [milieueffecten van de ruimtelijke veranderingen]
3. Financial aspects [financiële aspecten]

³This was not a hard requirement in the comparison of alternatives, as can be seen in the developing of alternatives.

⁴This is more than the previously prescribed maximum number of dwellings, but necessary to reach the desired 8,500 dwellings. Apparently, there was some flexibility in the previously defined maximum figure. Herfte had more flexibility than IJsselfront in increasing the number of dwellings.

⁵This was the minimum number of dwellings to gain sufficient support for new development in the Mastenbroekpolder

4. Combination of administrative, agricultural, and strategic aspects [bestuurlijke, agrarische en strategische aspecten]

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<p>Ten aanzien van deze keuze – aspecten – zijn de volgende criteria van belang:</p> <p>ruimtelijke aspecten Omvang van de locatie Uitbreidbaarheid Samenhang met de bestaande stad Voorzieningsniveau van wijckentra, bestaand en nieuw Gebiedspotenties ten behoeve van herkenbare gebieden met eigen identiteit</p> <p>milieueffecten van de ruimtelijke veranderingen Gevolgen voor het "groene" milieu met betrekking tot inpasbaarheid en compenseerbaarheid van bestaande waarden en uitstralingseffecten op c.g. draagkracht van de omgeving Gevolgen voor en beperkingen door het "grijze" milieu</p> <p>financiële aspecten Kosten verwerving en bouwrijkmaken Noodzakelijke voorinvesterings bovenwijkse infrastructuur Beheersbaarheid uitbreidingsmogelijkheid drempel – marktacceptatie</p> <p>bestuurlijke, agrarische en strategische aspecten Continuïteit van beleid op verschillende bestemmingsniveaus Acceptatie (politiek/bestuurlijke, bij bevolking en marktpartijen) Agrarisch belang Flexibiliteit (werkt het eventueel blokkerend) Snelheid van realisering De conclusie van de structuurschets plus is dat de locatie Stadshagen het meest in aanmerking komt voor de bouw van een nieuwe woonwijk.</p>	<table border="1"> <thead> <tr> <th rowspan="2">Criteria</th> <th colspan="7">Zoekgebied uitbreiding</th> </tr> <tr> <th>I</th> <th>II</th> <th>III</th> <th>IVA</th> <th>IVB</th> <th>V</th> <th>VI</th> <th>VII</th> </tr> </thead> <tbody> <tr> <td rowspan="2" style="background-color: #f0f0f0;">Water</td> <td>Kwantiteit</td> <td>+/</td> <td>+/</td> <td>-</td> <td>+/</td> <td>-</td> <td>+</td> <td>+</td> <td>+</td> </tr> <tr> <td>Kwaliteit</td> <td>+/</td> <td>+/</td> <td>-</td> <td>+/</td> <td>+/</td> <td>+</td> <td>+</td> <td>+/</td> </tr> <tr> <td rowspan="2" style="background-color: #f0f0f0;">Natuur</td> <td>Natuurbesch. wet</td> <td>+/</td> <td>-</td> <td>+/</td> <td>-</td> <td>+/</td> <td>+</td> <td>+</td> <td>+/</td> </tr> <tr> <td>Flora-/Faunawet</td> <td>+/</td> <td>-</td> <td>+/</td> <td>-</td> <td>+/</td> <td>+/</td> <td>+/</td> <td>+/</td> </tr> <tr> <td rowspan="2" style="background-color: #f0f0f0;">Cultuurhistorie en archeologie</td> <td>Cultuurhistorie</td> <td>+/</td> <td>+/</td> <td>+</td> <td>-</td> <td>+</td> <td>-</td> <td>-</td> <td>+</td> </tr> <tr> <td>Archeologie</td> <td>-</td> <td>+</td> <td>+</td> <td>+/</td> <td>+/</td> <td>-</td> <td>-</td> <td>+</td> </tr> <tr> <td rowspan="2" style="background-color: #f0f0f0;">Landschap</td> <td>Ruimtebeslag</td> <td>-</td> <td>-</td> <td>+/</td> <td>-</td> <td>-</td> <td>-</td> <td>+</td> <td>+/</td> </tr> <tr> <td>Waarden</td> <td>-</td> <td>-</td> <td>+</td> <td>+/</td> <td>+</td> <td>+/</td> <td>+</td> <td>+/</td> </tr> <tr> <td rowspan="3" style="background-color: #f0f0f0;">Verkeer</td> <td>Fiets</td> <td>+/</td> <td>+/</td> <td>+</td> <td>+/</td> <td>+</td> <td>-</td> <td>-</td> <td>-</td> </tr> <tr> <td>Openbaar vervoer</td> <td>+/</td> <td>+/</td> <td>+/</td> <td>+/</td> <td>-</td> <td>+/</td> <td>+/</td> <td>-</td> </tr> <tr> <td>Auto (aanst bestaande infra)</td> <td>-</td> <td>-</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+/</td> </tr> <tr> <td rowspan="2" style="background-color: #f0f0f0;">Woon- en leefmilieu</td> <td>Getuid</td> <td>-</td> <td>+/</td> <td>+</td> <td>+</td> <td>+</td> <td>+/</td> <td>+/</td> <td>+</td> </tr> <tr> <td>Luchtkwaliteit</td> <td>+/</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+/</td> </tr> <tr> <td rowspan="2" style="background-color: #f0f0f0;">Klimaat effecten</td> <td>Externe veiligheid</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+</td> <td>+/</td> </tr> <tr> <td></td> <td>+/</td> <td>+/</td> <td>-</td> <td>+/</td> <td>+/</td> <td>-</td> <td>-</td> <td>+/</td> </tr> </tbody> </table>	Criteria	Zoekgebied uitbreiding							I	II	III	IVA	IVB	V	VI	VII	Water	Kwantiteit	+/	+/	-	+/	-	+	+	+	Kwaliteit	+/	+/	-	+/	+/	+	+	+/	Natuur	Natuurbesch. wet	+/	-	+/	-	+/	+	+	+/	Flora-/Faunawet	+/	-	+/	-	+/	+/	+/	+/	Cultuurhistorie en archeologie	Cultuurhistorie	+/	+/	+	-	+	-	-	+	Archeologie	-	+	+	+/	+/	-	-	+	Landschap	Ruimtebeslag	-	-	+/	-	-	-	+	+/	Waarden	-	-	+	+/	+	+/	+	+/	Verkeer	Fiets	+/	+/	+	+/	+	-	-	-	Openbaar vervoer	+/	+/	+/	+/	-	+/	+/	-	Auto (aanst bestaande infra)	-	-	+	+	+	+	+	+/	Woon- en leefmilieu	Getuid	-	+/	+	+	+	+/	+/	+	Luchtkwaliteit	+/	+	+	+	+	+	+	+/	Klimaat effecten	Externe veiligheid	+	+	+	+	+	+	+	+/		+/	+/	-	+/	+/	-	-	+/
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Figure 5.4: Two lists of criteria used to choose a location for new development. Left/hand side: A list from ‘Startnotitie Milieueffectrapportage Stadshagen’ (Gemeente Zwolle, 1991, p7 & 8) used to decide from among Stadshagen, Herfte, and IJsselfront. Right-hand side: A more recent list from the ‘Structuurplan Zwolle 2020’ (Gemeente Zwolle, 2008, p. 59), containing water-related criteria (red rectangles). This difference demonstrates the changes that have occurred in recent decades.

The three alternatives were compared based upon 18 criteria within the four categories (left side of Figure 5.4). The comparative study aiming to select the most suitable location presented a valuation matrix, comparable with a multi-criteria analysis (MCA). The exact numbers and weighting factors used in that analysis are in the Structuurschets Plus report. A summary of this study, without the underlying assumptions and input numbers, formed part of the MIRT document (Gemeente Zwolle, 1991, p.19-24). The outcome of the valuation matrix was an overall score for every single site: Stadshagen = 2.4, Herfte = 1.7, and IJsselfront = 1.5. These scores supported the existing preference for the Stadshagen alternative. In 1994, the EIS was presented, and assessment recommendations followed in May 1995. This advice did not change the choice of Stadshagen, and functioned as an advisory assessment rather than a binding one. The EIS was just one of multiple criteria for choosing the location, as spatial planners typically consider a wide range of variables.

In June 1991, the municipality stated an initial preference for Stadshagen over Herfte or IJsselfront, but the official choice was made after the publication of the mandatory environmental impact statement (EIS) that resulted from the environmental impact assessment (EIA). This EIA considered two elements, the location choice and the design (Commissie voor de milieu-effectrapportage, 1995). In January 1993, a commission assessed the location choice. It criticised the fifth requirement (i.e., a single, compact location). The requirement stipulated that the new development had to take place at one location, due to the higher rate of return on the investment. The commission explained that multiple locations could achieve the same rate of return as a single site and noted that using the return on investment as a guiding criterion would have been more appropriate than specifying a single requirement of a compact location.

Choose alternative

In this case, the MLS Explorer could have proved useful in providing an exploratory assessment of the flood risk during the EIA evaluation of the potential locations and designs. In terms of the six spatial planning phases, this means during three phases; set objectives (3th) (e.g. a maximum present value of the flood could be calculated), develop alternatives (4th) (e.g. different neighbourhoods could have been explored in order to take decisions upon the design), and compare alternatives (5th) (e.g. the selected alternatives could have been drawn in order to find an indication of the expected flood risk for that alternative). In the end, the final choice can be made with an MCA. The flood-risk assessment could have provided input for one of the criteria.

When?

The above-described documents gave insight into the main actors during the individual planning phases, and therefore, those parties that could have been interested in information from the MLS Explorer. The roles of these parties are shortly described before indicating who would probably have been the most interested in using the Explorer.

Who?

Province: According to Menno ten Heggeler (Personal interview, 2016), programme manager from the province of Overijssel, the MLS Explorer is less relevant on the provincial level, since the province operates on larger scale than that for which the Explorer was intended. However, the province establishes guidelines for lower-level governments, which could possibly use the Explorer to comply with those conditions. Ten Heggeler said that the province would appreciate it if the lower-level governments used such an Explorer. However, at particular times, the province might have an interest in the Explorer, such as for projects exceeding municipal borders and when an EIA is required for provincial decisions. The province of Overijssel partially manages the flood risk, which is recognised as a provincial interest (Provincie Overijssel, 2009a, art. 2.14.3 & art. 2.14.4), by obliging municipalities to include a flood-risk paragraph in their spatial plans. (Neuvel & Boxman, 2011). This requirement forces municipalities to conduct brief studies on the flood-risk consequences associated with their spatial plans and to include a flood risk paragraph in their new zoning plans. The MLS Explorer would be an appropriate instrument for such research.

Municipality: As the preceding paragraph made clear, the municipality could use the Explorer for writing the flood-risk paragraphs that must be included in their spatial plans. Moreover, the Explorer could be used to facilitate communication with the province or the EIA commission, which happened quite often in this case.

Water board: Likewise, for the water board, the MLS Explorer is mainly interesting as an instrument for communicating with municipalities or developers. The water board has expert staff who can perform more calculations. However, these calculations will be needed in a later stadium of the whole planning process (e.g. in the design of a final option).

Developers and housing associations: A manager real estate of a housing association that owns dwellings in Stadshagen stated that it would be in an instrument like the MLS Explorer (van Rijen & Bruggink, 2016, Personal interview). However, organisations like this housing association have a different time perspective with respect to costs and benefits. They are mainly interested in flood-related problems that occur once every 5, 10, 25, or 50 years, instead of in floods that can occur once every 250 years, or even less often. The reason for this difference is that such organisations are willing to take measures that pay themselves back within 40 years and rather accept the risk. Or perhaps use insurance for the longer perspective. This is because the dwellings with which they are concerned are mainly built to last approximately 50-100 years. For such users, the Explorer should contain measures aimed at preventing the type of damage caused by smaller weather events that occur more often. For such scenarios, measures such as raising houses by a few decimetres can achieve a significant risk reduction.

Stated differently, the scenarios of interest are high probability/low impact ones and low probability/ high impact ones. Low probability/ low impact is acceptable, and high probability/high impact definitely needs measures. For the first type of scenario, housing owners are willing to take action, but for the second category, homeowners prefer to purchase insurance or accept the risk.

Useful information for those private parties includes the present value of different MLS measures and the present value of potential damage. Van Rijen also mentioned that such actors would be highly interested in the consequences of, and measures to address, pluvial (caused by precipitation) flooding, instead of only fluvial (from a river) and coastal flooding (van Rijen & Bruggink, 2016).

5.2. CASE 2: CHOICE OF A DESIGN FOR A SOUND BARRIER

The second case had the same geographical scope, but it analysed upon a different action. Therewith, the events took place more recently than the first case. The case centred on selecting a design for a sound barrier aimed at delaying at potential future flooding.

Problem
identification

The problem in this case arises from the plans for flexible water level in the Lake IJssel [IJsselmeer], which was a solution for several problems that resulted from the climate change (Min. van I & M & Min. van EZ, 2015). The National Delta Programme 2012 stated that the water level in the Lake IJssel should be more flexible in the future to deal with several delta challenges converging in the IJssel-Vecht region (Min. van I & M & Min. van EZ, Len I, 2011). According to Gerrit Vrieling (2016, Personal communication), the 1.5-metre increase in the water level created several potential problems around Zwolle. The greater need for collaboration between spatial planners and water managers was explicitly expressed by both national as local government during the case period. In 2008, the Second Delta Commission recommended strengthening the political-administrative organisation of water safety and fostering closer links between flood-risk measures and spatial development (Deltacommissie, 2008). The strengthening of the water safety stakes in spatial plans was incorporated into

the provincial policy by considering flood risk as a provincial interest, as stated in the Surroundings Vision [omgevingsvisie] (Provincie Overijssel, 2009b). The Provincial Surroundings Regulation [omgevingsverordening] of 2009 obliges municipalities to include a 'flood-risk paragraph' in their spatial plans (Provincie Overijssel, 2009a, art. 2.14.3 & art. 2.14.4), demonstrating that this problem is recognised at different governmental levels.

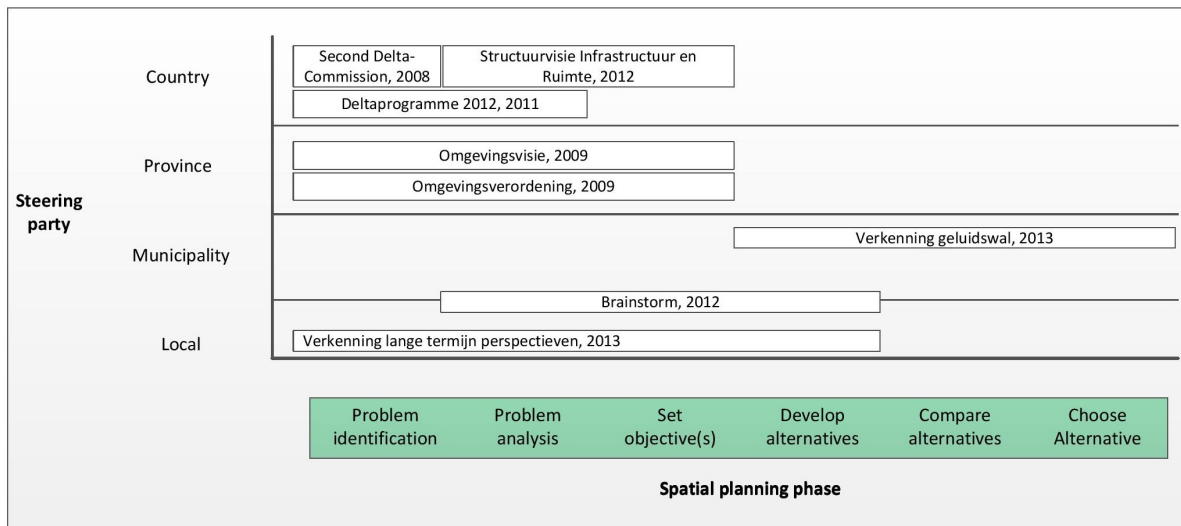


Figure 5.5: Planning levels and phases for the second case. Second Deltacommission = (Deltacommissie, 2008), Deltaprogramme 2012, 2011 = (Min. van I & M & Min. van EZ, L en I, 2011), Structuurvisie infrastructuur en Ruimte 2012 = (Min. van I & M, 2012), Omgevingsvisie 2009 = (Provincie Overijssel, 2009b), Omgevingsverordening 2009 = (Provincie Overijssel, 2009a), Verkenning lange termijn perspectieven, 2013 = (H+N+S Landschapsarchitecten et al., 2013), Brainstorm 2012 = (Enno Zuidema Stedenbouw et al., 2012), Verkenning geluidswal, 2013 = (projectteam Stadshagen & projectteam IJVD Zwolle, 2013)

Recognition of the problem resulted in initiatives analysing the problem and brainstorming potential solutions. Since greater cooperation was a goal, this process relied on collective brainstorming sessions with many parties. Single reports often included the problem analysis with the problem identification and a list of objectives, therefore, the actual problem analysis was not always easy to distinguish. However, the problem analysis was identified in several reports (Enno Zuidema Stedenbouw et al., 2012; H+N+S Landschapsarchitecten et al., 2013; Provincie Overijssel, 2009a), see figure 5.5. One of these brainstorm sessions in 2012 had approximately 40 participants representing different organisations, such as the water board, the municipality, the Ministry of Infrastructure and Environment, the province, the Directorate General for Public Works and Water Management [Rijkswaterstaat], and several private parties (Enno Zuidema Stedenbouw et al., 2012). Certain participants were experts who could explain flood-risk aspects. The main objective of that session was to think about how two future neighbourhoods, 'De Tippe' and 'Breezicht' (see Figure E.1) could be designed to reduce the flood risk. In this session it was stated that MLS was a new concept on the political agenda, so its exact meaning was still quite hazy. As a result, the participants found it difficult to use this new concept in practice (Enno Zuidema Stedenbouw et al., 2012, p. 25).

Problem analysis

The report from the brainstorming session mentioned certain objectives, namely: preventing casualties and reducing damage, increasing the discharge capacity, and gaining more insight into the potential of several compartment measures⁶. In addition, objectives were stated on the national level in the Structure Vision Infrastructure and Space [structuurvisie infrastructuur en Ruimte] (Min. van I & M, 2012), only 10 days before the workshop. That document stated that cities needed to be (re)developed in a climate-resilient way. This second case highlights that one actor's goal may be seen as a problem by another entity, as the flexible water level in Lake IJssel was an objective on the national level, but a problem on the municipal level.

Set objectives

⁶Compartment measures are aiming to divide large areas into smaller sub-areas which are closed, or can easily be closed to prevent the rest of the area from flooding

Develop alternatives	Based on the problem analysis, which mainly took place during the brainstorming session, two alternatives were devised and further evaluated. The first option was a sound barrier as a compartment dike ⁷ and the second option was a sound barrier as compartment rampart. ⁸ The main difference between these two categories is that the first one has an official status and therefore will be significantly more expensive and give more certainty.
Compare alternatives	Due to a lack of knowledge, it remained difficult to determine how useful a flood-protection sound barrier would be. Therefore, two project teams from Stadshagen and the IJssel-Vecht Delta carried out further research, comparing both alternatives via an exploratory study (projectteam Stadshagen & projectteam IJVD Zwolle, 2013).
Choose alternative	The team concluded that an official compartment dike would be significantly more expensive. For that reason, it was decided to implement the compartment rampart, which did not need to meet a long list of requirements.
When?	In this case, the MLS Explorer would have had the most added value to the brainstorming sessions, which took place in the phases of problem analysis, set objectives and design alternatives. During those meetings, the Explorer could have functioned as communication instrument to explain concrete flood risks in a specific location and measures of (financial) interest. The fifth phase of comparing alternatives happened in the form of a study conducted by specialists who are able to make expert judgements on the basis of their knowledge. To a certain extent, this insight of the experts is comparable with the results from the MLS Explorer, although specialists can provide a fuller picture. However, the question remains of how much information planners need at such a moment. It can be stated that the added value of the MLS Explorer is potentially high in the phase of problem analysis. During this research, the author identified in the answers from several interviewees (van Beek & Vrouwe, 2016 ; Vrieling, 2016 , Personal interview), that within these two cases in the first instance, the flood risk was not on the political agenda. Probably because there was no recent history of flooding in that area. According to Gerrit Vrieling, this lack of attention for flood risk is still the case, as floods only receive heightened political attention during the period directly following such an event. Thus, during periods in which flooding has not recently occurred, the Explorer can prove its utility after it is improved.
Who?	Currently, the municipality of Zwolle is searching for solutions for the consequences of the flexible water level in the Lake IJssel. The inner city of Zwolle is actually outside the dikes and in direct connection with this lake. During that search for applicable solutions, the MLS Explorer could definitely be valuable during the exploratory phase of developing and comparing alternatives (van Beek & Vrouwe, 2016 , Personal interview). This 'exploratory' trait is an important aspect of the MLS Explorer, and it means that the information does not have to be very detailed; rather, it must offer an estimation within certain boundaries. If alternatives have to be compared with real calculations at a later date, the municipality will ask the water board to conduct that assessment. In the end it can be concluded that during the comparison of alternatives the province of Overijssel; Water Board Drents Overijsselse Delta ⁹ ; and the municipalities Zwolle, Kampen and Zwartewaterland, all had a role in the spatial planning process, but mainly for the municipality and the water board it would have been useful if they had an instrument that can rapidly present some information about the flood risk situation.

5.3. CASE 3: EXPLORATORY SEARCH FOR MLS SOLUTIONS

Problem identification

The third case took place in a different region than the first two, as the action occurred in the region around Venlo (see chapter 4.2). The identification of a possible problem started with a widely shared recognition under governmental organisations, that water-safety policy required reconsideration ([Zanting & Noordam, 2008](#), p. 4). This recognition was underpinned by conclusions from the Dutch Safety Mapped study [Veiligheid Nederland in Kaart (VNK)] ([Rijkswaterstaat, 2005](#)), which called for a new approach able to anticipate

⁷This compartment dike has a formal status as a flood barrier and therefore requires significant investment and maintenance.

⁸A compartment rampart has no formal status but is designed to initially slow down a flood

⁹In those days 'Groot Salland, this board has merged with 'Reest en Wieden' on 1 January 2016.)

newly discovered failure mechanisms. That report also included a more detailed cost-benefit analysis, which stated the costs of the measures and the level of risk reduction associated with them. This new approach to water safety was further explored in another report about water safety in the 21st century [Waterveiligheid 21e eeuw] (Zanting & Noordam, 2008), which introduced the concept of MLS.

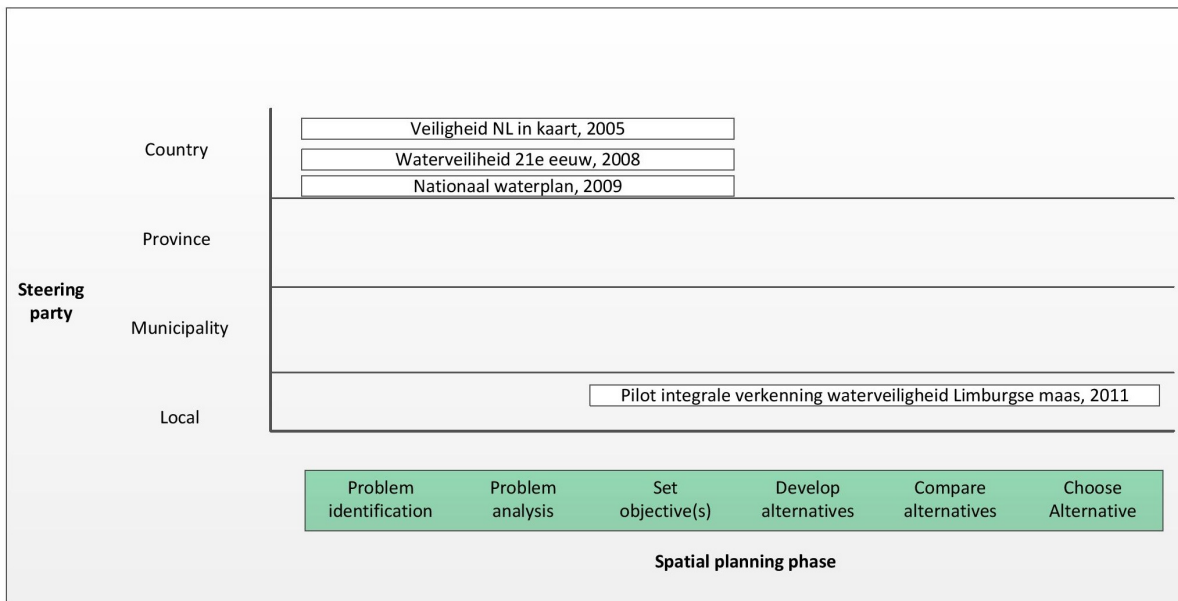


Figure 5.6: Different planning levels and phases, filled in with plans that were explained in the third case. Veiligheid NL in kaart, 2005 = (Rijkswaterstaat, 2005), Waterveiligheid 21e eeuw, 2008 = (Zanting & Noordam, 2008), Nationaal waterplan = (Min. van V & W, 2009), Pilot integrale verkenning waterveiligheid Limburgse maas, 2011 = (Infram, CSO and HydroLogic, 2011)

Since this case does not involve a current problem, the researcher did not identify the problem analysis. Rather, only a potential problem identification has occurred. However, fundamental, explanatory research was needed to obtain a clearer picture of how to use MLS. The motivation was the first National Water Plan ¹⁰[Nationaal Waterplan](Min. van V & W, 2009), which set aside a budget to experiment with pilot projects to understand the potential of the MLS concept in more concrete terms. A new idea entails a general lack of experience and the inability to predict results in advance.

Problem analysis

One of these pilot areas focused on dike-rings 68 and 90. This research is used to identify the phases of setting objectives, develop alternatives, compare alternatives and in the end the choice for an alternative. The objective of that project was to investigate the applicability of different potential MLS measures from all three levels.

Set objectives

To identify the best MLS measures, three alternative strategies were formulated: (1) ‘zero victims’, (2) ‘live with the river’, and (3) ‘tamed river’. These strategies each emphasised a specific MLS aspect, and together, they were designed to yield a broad collection of information on MLS applications. The strategy areas consisted of a variety of measures that are explained and evaluated by Infram in text and numbers (Infram, CSO and HydroLogic, 2011, p. 42-47; tables with a further explanation are in appendix E).

Develop alternatives

The three strategies, which were chosen for the MLS research, were compared in terms of the costs of the measures, effects on damage levels, and effects on the number of victims. The remaining criteria were safety, robustness, feasibility, economic effects, environmental effect, spatial organisation, and policy. These criteria were associated with the sub-criteria in Figure 5.7. The strategies received qualitative scores indicating their alignment with these criteria. A plus sign meant a positive review, a zero was neutral, and a minus sign was negative. The data from the damage- and victim-related comparisons came from the High-Water Information System - Damage and Victim Module [Hoogwater Informatie Systeem - Schade en Slachtoffer Module;

Compare alternatives

¹⁰This was the successor of the previously mentioned Note Watermanagement [Nota Waterhuishouding]. The national government’s water law [waterwet](2009) updates the water policy plan every six years. The second National Water Plan was published in 2015

HIS-SSM],¹¹, which computer models (Waqua and Sobek) used to calculate potential damage and victims figures for specific scenarios in dike-ring 68. The models' output was employed to further assess the strategies.

<i>Thema</i>	<i>Aspect</i>
Veiligheid	Slachtoffers (en getroffen)
	Beïnvloeding waterveiligheid aangrenzende dijkringen (afwenteling)
Robuustheid	Externe gebeurtenissen, klimaatverandering
	Ruimte voor natuurlijke processen
	Duurzaamheid van beheer
Haalbaarheid	Draagvlak
	Technische uitvoerbaarheid
	Realisatietermijn
Economische effecten	Kosten
	Vermeden schade
	Vitale objecten
Omgeving	Effecten op gebruiksfuncties
Ruimtelijke ordening	Functiewijziging
Beleid	RO-beleid
	Waterbeleid

Figure 5.7: List of criteria and sub-criteria used to compare MLS strategies (Infram, CSO and HydroLogic, 2011)

Choose alternative

After the comparison, advisors from Infram selected a combination of individual measures that demonstrated the most potential. These were:

- Measures from the third MLS level aimed at increasing the preparedness of civilians: Such measures are relatively inexpensive and can potentially produce relevant results with respect to victim reduction. However, the authors of the report mentioned that the quality of data used for the simulations were lower than those used in other locations in the Netherlands, and so the recommendation was made to further analyse these effects in the near future.
- Compartment measures, especially around the Roermondse Poort, if necessary, combined with a Delta dike.
- Expansion of 'room for the river' to lower water levels.

When?

In this case, the use of the Explorer would have been valuable during the comparison of the alternatives. The existing assessment used a symbolic system (e.g. plus, zero, and minus) and few numeric variables. The Explorer, however, could have provided real numbers for the expected damage, number of victims, and costs, these numbers are useful estimations for the municipality since it gives the possibility to take decisions based upon quantitative and objective argumentation.

Who?

In this case, few parties were involved. Mainly, the national government played a role, as did the local bureau that performed the research commissioned by several governments. This configuration was probably due to the fundamental nature of that research. The national government provided the funding for the study, and the National Ministry of Infrastructure and Environment and the province of Limburg commissioned it. The parties with the greatest potential interest in the Explorer are the municipality and the advisory bureau. The municipality could use the tool to get an overall picture of the flood risk, and the advisory bureau could use it to compare alternatives.

5.4. CASE 4: SEARCH FOR NEW DEVELOPMENT IN VENLO

The fourth case needs a short explanatory introduction, since it takes place around a 'start decision' in order to qualify for funding from a National fund, named MIRT¹² [Meerjarenprogramma Infrastructuur Ruimte en

¹¹This module contains information that can be used to calculate expected damage and victim outcomes. The Dutch national government and individual provinces commissioned its development.

¹²The MIRT programme is a national fund that local governments can use to finance plans. To become eligible for such funding, the applicant has to meet the conditions outlined by the government. One of these conditions is a prescribed procedure.

Transport] programme. This start decision is expected to be followed up by an exploratory study searching for a solution to multiple problems identified in Venlo. The research was aiming for a win-win solution by simultaneously enhancing the spatial quality and lowering the flood risk. The main focus in the analysis was on the different phases that can be identified within the standardised MIRT processes. This is an interesting topic, since MIRT is a general national funding programme that provides financial support to specific projects. As this process is commonly used, it could play a role in potential future MLS projects, including those involving the MLS Explorer. During the analysis of this case, the project was still in its pre-MIRT phase. Thus, setting objectives was the last step that had been achieved, meaning that this analysis only considers the first three steps of the spatial planning model. The central action thus did not hinge on selecting an alternative, but on setting the objectives.

MIRT process

To understand this case, some familiarity with the MIRT process and its role in the spatial planning model is necessary. The MIRT process is a standard procedure for large projects in the Netherlands, making it particularly interesting to identify the stage with the most promise for the MLS Explorer. The formal MIRT procedure contains four decision moments: (1) start decision [startbeslissing], (2) preference decision [voorkeursbeslissing], (3) project decision [projectbeslissing], and (4) handover decision [opleverbeslissing]. The official phases, which take place between these decisions are; the exploratory phase (between points 1 and 2), the plan development phase (between points 2 and 3), and the realisation phase (between points 3 and 4; see Figure 5.8). The national government has prescribed a list of requirements for each phase that have to be fulfilled before financial funding for the next phase is granted (Min. van I&M, 2011). Before this formal process, there is an informal stage during which the local government must establish an areal agenda [gebiedsagenda] to be used as input for the start decision. When this agenda is approved, the project obtains 'MIRT exploration' status. When the areal agenda is deemed insufficient, it must be improved (see Figure 5.8). The informal MIRT research results in a research agenda, which has to meet the following requirements for a start decision:

- Involved parties must agree on the urgency of the assignment.
- There is a presence of national interest.
- A budget adequate for completing the task within the proposed time line must be available, or realistically available within the foreseen time scope.
- The substantive requirements stated in the information profile must be met.

This MIRT process was compared with the spatial planning model explained earlier in this chapter. Their processes differ slightly, since every phase between two decisions has its own scoped process. Each scoped process has similarities with the whole spatial planning model. This structure in line with Spit and Zoete's statement that spatial planning processes are cyclic, with individual phases occurring several times (Spit & Zoete, 2006, P. 86). Figure 5.9 visualises one approach to this system. The lower green frames contain the same steps as the higher ones, but they take place on a more concrete level. This chapter focuses on the informal part of the process and therefore only explains the first steps of the spatial planning model.

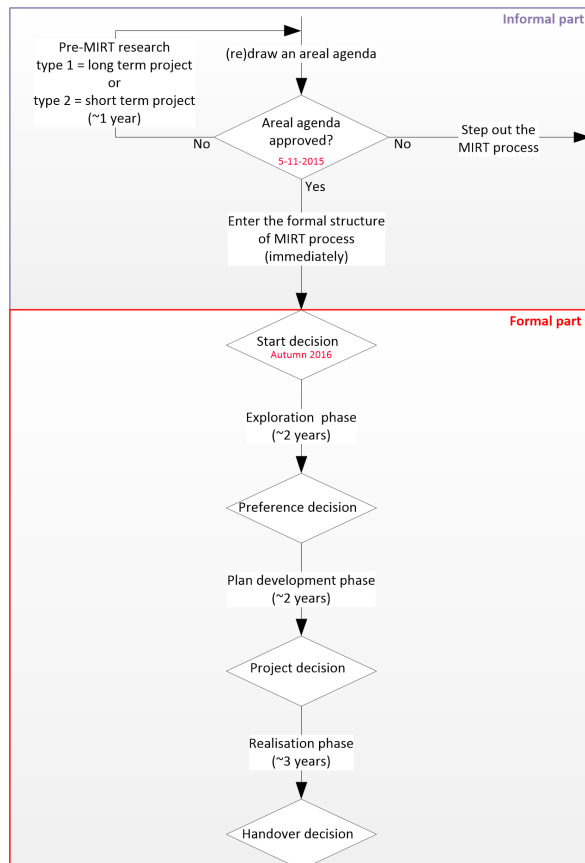


Figure 5.8: Overview of the MIRT process, found in Min. van I&M (2011). The Meuse Venlo project entered the exploration phase in October 2016

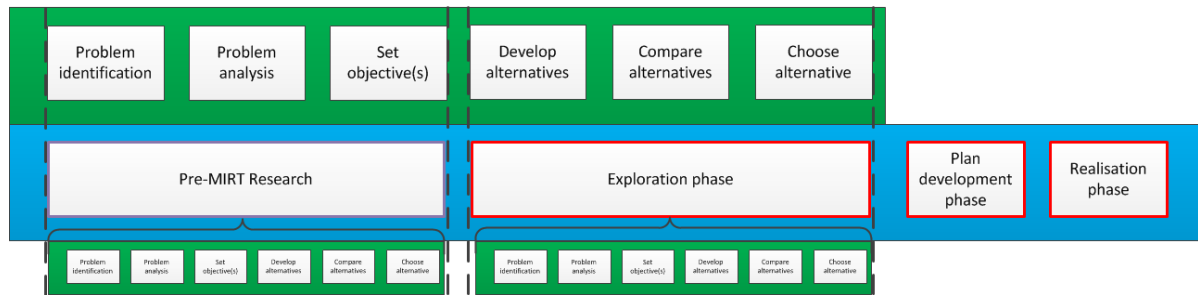


Figure 5.9: Spatial planning model (green frame) compared to the MIRT process (blue frame). Within the separate MIRT stages, distinct spatial planning phases are recognisable, since objectives can be compared and selected to subsequently develop alternatives.

The Case

On 7 October 2015, an agreement of intent was signed by the Provincial Executive Council of Limburg, the Executive Board of the Water Board Peel en Maasvallei, and both Colleges of Mayer and Aldermen of Peel en Maas and Venlo. This agreement, together with the provincial areal-agenda ([Provincie Limburg, 2012](#)), formed the foundation of the informal MIRT research which consisted of several reports. The overall research is on a higher geographical level that contains multiple projects along the Meuse. This analysis was only towards the locations around Venlo (see [Figure 4.3](#)).

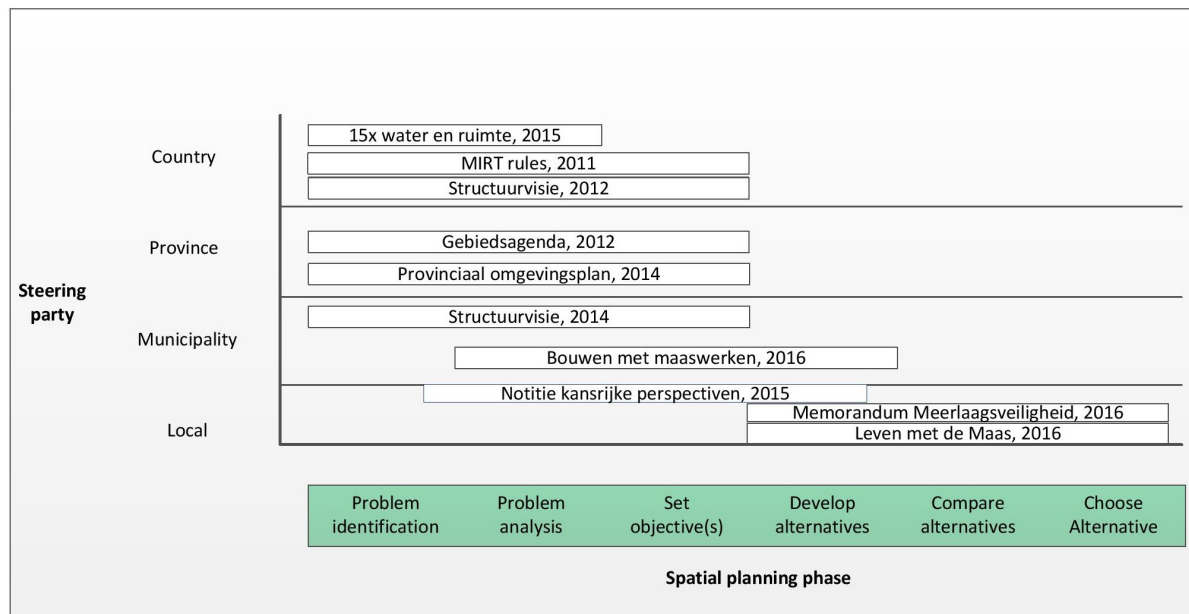


Figure 5.10: Planning levels and phases for the fourth case. 15x water en ruimte, 2015 = ([Min. van I & M, 2015](#)), MIRT rules, 2011 = ([Min. van I & M, 2011](#)); Structuurvisie, 2012 = ([Min. van I & M, 2012](#)); Gebiedsagenda, 2012 = ([Provincie Limburg, 2012](#)); Provinciaal omgevingsplan, 2014 = ([Provinciale staten van Limburg, 2014](#)); Structuurvisie, 2014 = ([Gemeente Venlo, 2014](#)); Notitie kansrijke perspectieven, 2015 = ([Lieveense CSO & BVR, 2015](#)); Leven met de Maas, 2016 = ([Lieveense CSO & BVR, 2016](#)); Memorandum Meerlaagsveiligheid, 2016 = ([Terpstra & Leenders, 2016](#));

Problem identification

In this fourth case, multiple documents identified the problem and partly laid out objectives. The areal agenda [gebiedsagenda] of Limburg mentioned two problems with the so-called Maas Venlo project ([Provincie Limburg, 2012](#)). The first problem emerged at two moments, 1993 and 1995, in which Meuse water levels were particularly high.¹³ After these events, the government decided to build temporary dikes along the Meuse. Initially, these dikes lacked an official status, since they were temporary. This changed in 2006, when it became clear that climate change was having a higher impact than previously expected. The initial measures were deemed not sufficient, and the quays along the Meuse in Limburg had been classified as primary dikes, meaning that they needed to satisfy certain criteria. In January 2017, new norms came into force,

¹³In 1993 and 1995, discharge was measured at 3,120 m³/s and 2,870 m³/s, respectively, while the average discharge level is approximately 230 m³/s.

which means that it is likely that the dikes will need to be even higher in the future. This change resulted in protests among people living close to the dikes who did not accept the disruption of their view (Min. van I & M, 2015, p. 56). The second problem is related to the fact that while Venlo is currently a logistics hotspot, it needs to expand to maintain that position. The current prediction is that within five years, the available space will be insufficient to meet the demand for expansion (Lievens CSO & BVR, 2015). The identified problems were also highlighted in both Municipal and ministerial Structure Visions (Gemeente Venlo, 2014; Min. van I & M, 2012). Furthermore, the Provincial Surroundings Plan Limburg [Provinciaal omgevingsplan Limburg] mentioned that the changing climate is expected to result in more intensive rainfall and higher discharge throughout the Meuse (Provinciale staten van Limburg, 2014). For this reason, the municipality has introduced new approaches in its Spatial Structure Vision, which are summarised in statements like; 'living with the Meuse' [Leven met de Maas]; 'space where possible, dikes where necessary' [ruimte waar het kan, dijken waar het moet]; and potential MLS measures (Gemeente Venlo, 2014, p. 58).

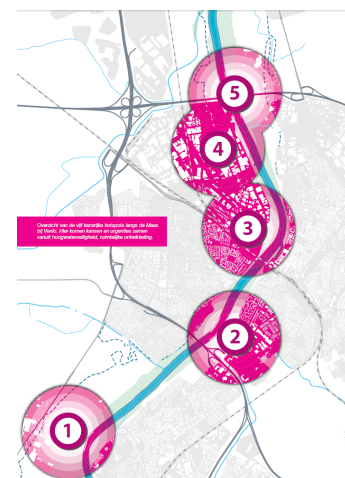
The problem was analysed to develop an agenda containing research objectives and potential avenues for further research. This analysis started in 2014 with the formation of Koploperproject 'Maas Venlo'. The Municipality of Venlo, in cooperation with other parties, gave two bureaus ('Lievens CSO' and 'BVR') the task of translating the municipal ambitions into an areal agenda. The result was a report entitled 'Note Promising Perspectives' [Notitie kansrijke perspectieven] (Lievens CSO & BVR, 2015). This report highlighted promising perspectives for flood resilient spatial development in the 'Koploper Project Maas Venlo'. The areas with greatest potential were five 'hotspots' in Venlo (see figure 5.11). These hotspots represented the alternatives within the problem analysis. Thus, the step 'develop alternatives' took place within the problem analysis (see Figure 5.9).

Problem analysis

As was the case for the problem analysis, the initial objectives were set on multiple governmental levels. In the national structure vision, tasks related to Venlo included 'strengthening the primary defences and implementing the area-specific sub-programme 'Rivers' from the Delta Program' and 'Conducting research on spatial and infrastructural tasks around Greenport Venlo' (Min. van I & M, 2012, p. 79). The actualised areal agenda from 2012 mentioned that these objectives would play a key role in allowing the province to realise its political agenda (Provincie Limburg, 2012). The objectives for the Meuse-Venlo project were outlined in Note Promising Perspectives of 2015. These were improving water safety in Venlo and upstream areas, enhancing the urban structure by providing suitable opportunities for regional economic development, and spatial quality (Lievens CSO & BVR, 2015, p. 11). The fact that the objectives touched on multiple governmental levels indicates the national interest, which is a requirement to become a MIRT project. The objectives that were stated on a national and provincial level can be placed in the higher green frame from figure 5.9. The municipal objectives that were stated in the Note Promising Perspectives can be placed in the lower green frame, since these will be used to develop and choose alternatives. The chosen alternatives, combined with results of the other research programmes, were presented in the Administrative Consultation MIRT [Bestuurlijk Overleg MIRT (BO MIRT)] of 2016 to obtain the 'exploration' status. After this 'MIRT exploration' status was obtained it entered the formal phase in which the alternatives will be further elaborated in order to eventually end up with a final choice.

Set objectives

Now the scope continues on the municipal level of the lower green frame in figure 5.9. After the objectives were stated the Note Promising Perspectives, this same report explains the alternatives that were further analysed to find out how they could contribute in reaching those objectives. The five hotspots (or alternatives) were (1) 'Baarlo': a relocation of the dike that results in significant water level reduction of the Meuse (2) 'area surrounding Molenbossen and a hospital': a relocation of the dike combined with relocation of the parking facilities of the hospital, (3) 'Centre of Venlo and the former barracks ground': streamlining the water flow profile, combined with redevelopment of an old barracks ground, (4) 'area around the industrial port': improvement of a water barrier combined with expansion of the industrial port, (5) 'Venlo Velden'; again a relocation of the dike combined with a new secondary channel with new recreational harbour. See Figure 5.11 for all hotspots.



Develop alternatives

Figure 5.11: Five hotspots in Venlo with high potential for combining flood safety and spatial development. Figure from (Lievens CSO & BVR, 2015, p. 15)

Compare alternatives	These alternatives were compared by the Advisory and engineering bureau Lievens CSO and advisers in spatial development BVR (2015). The comparison was done in various manners by tracking numeric information (e.g. costs and benefits, effect on the water level) but also conversations with the local residents about topics like the urgency.
Choose alternative	All researches were bundled in one report, which concluded that hotspot 4 and 5 were most fruitful to proceed in the MIRT process. Hotspot 1 was had more legitimacy in the Flood Protection Programme [Hoogwaterbeschermingsprogramma (HWBP)], which is focusing on protection against high water. The other two hotspots were set aside for this moment in time.
When?	This last case is still underway, which makes it particularly interesting. However, that fact also makes it more difficult to fully analyse the process. That said, interviews with several people involved in the project during these first three steps stated that the MLS Explorer could potentially be useful (van der Hagen, 2016; van Hal, 2016). For example, it could first be used to analyse the current situation (problem analysis), secondly to set an objective that can be used to assess all alternatives and thirdly, the expected flood risk can be analysed for all five hotspots selected for new development (compare alternatives). The province or municipality's upper limit for the present value of expected damage could be used as a criterion for developing new alternatives.
Who?	tating who would have the most interest in using the Explorer remains difficult at this point. Depending on the type of information, either the municipality or the water board, or both might find it useful. In most cases, the water board requires more detailed information, meaning that it would likely have more interest in the MLS tool. Moreover, an organisation like BVR Advisors would certainly be interested in using an instrument like the MLS Explorer to assess alternatives (Bomas, 2016).

5.5. CONCLUSIONS

The questions in this chapter were to find out when and by whom an instrument like the MLS Explorer is most interesting to be used. The answer can be visualised in the same graph that was employed for all the cases in this chapter. For every case it was analysed which information is presented in different reports that were used on different governmental levels. The reports that contained information that had most similarities with the information that the MLS Explorer presents were found in the blue rectangle in Figure 5.12. This rectangle is partially filled and partially empty, in the filled rectangle the Explorer can really be used for aspects that are substantively dealing with flood risk, for the non-filled rectangle it is more to explore the situation with less emphasis on flood risk. Still it is useful to start using the Explorer in the beginning of the whole process, for example to find out if there actually is significant flood risk at a location (problem identification) and how big the risk is for that situation (problem analysis). Since the problem identification in this context was seen as the identification of problems like housing shortage, the Explorer is not explicitly meant to identify this problem. After the problem is identified, it was found in the second and fourth case that the problem analysis would have been suitable for using the MLS Explorer (e.g. how high could the water come without any flood delaying sound barrier?). Setting the objectives were explicitly found in the first case (defining requirements and criteria to develop/assess alternatives) and the fourth case (maximal flood risk for a hotspot). The phases of develop- and compare -alternatives were almost in all cases explicitly found. Only in third case the development of alternatives existed of picking three extremes with its own identity, and in the fourth case the comparison of alternatives wasn't found, but this case was still in the beginning of the whole spatial planning process.

The last phase of compare alternatives can be seen as the interface between more suited to use the the MLS Explorer or the MLS tool. Depending on the required level of detail and the size of the project, both can be interesting to use during the comparison of alternatives. The larger the project, the higher the budget, and the greater the likelihood of a specialist, who is capable of using the MLS tool, is being hired. The Explorer could be used to indicate the lack of a significant flood risk, and therefore, the lack of a need to take it into account during the spatial planning process. That said, the fact that precipitation might represent a greater risk in the future should be kept in mind.

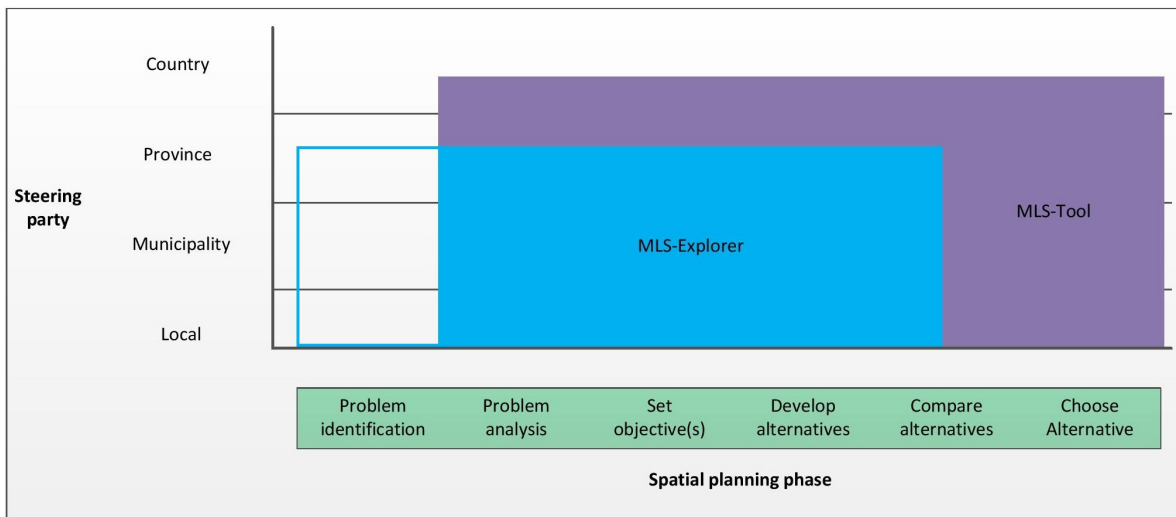


Figure 5.12: Domains with the most potential for the MLS Explorer and the MLS Tool. The blue rectangle is partially filled since it can be used for analysis, and partially non-filled since it will be more suited for quick exploration.

For who the Explorer is most interesting to use is mainly the local parties like municipality or private organisations (bottom of the vertical axis), since they need concrete numbers to compare alternatives. In contrast, the central governments are often setting the scope within which the local government is allowed to form a spatial plan. For example several areas which can be used as optional alternatives for the foreseen purpose. The province is on the interface of more interesting to use the Explorer or the Tool. Most of the times the budget will be large enough to hire an expert, but it can be interesting to first perform a rough exploration with the Explorer.

Besides the phases when- and persons by whom -the explorer is most interesting to be used, this chapter also yielded some conclusions in the form of four explicit requirements that should be met by the MLS Explorer.

ACCESSIBLE AND RAPID TO USE

Since the Explorer has an exploratory function and is best suited for the beginning of the planning process, it must be quick and accessible. Within a few minutes, it should provide a decent impression of the flood risk in an area. Moreover, additional software should not be a requirement; everybody with a computer and an internet connection should be able to use the tool. If no need for installing software makes it easier for potential users to try out the usage of the instrument. Or a user who already knows it, can show it on a tablet.

FLEXIBLE

A difference between the MLS Tool and the MLS Explorer pertains to possibilities for calculations, and therefore flexible in the purpose where it can be used for. In the Tool, many assumptions can be adjusted to determine how the adjustments influence the outcomes. The Explorer does not need to be that flexible, but it can be made more flexible that it is right now. Such that different types of users will be able to use it in useful manner. Users who are unfamiliar with flood-risk statistics should be able to rely on maps, colours (e.g. a traffic light with green, orange and red), and conclusions, whilst users who have more knowledge about the subject should have the opportunity to see the calculated results. When this flexibility is realised, this makes it possible to use the Explorer during multiple stages of the planning process. At early stages, raw estimations and first insights into the potential consequences are important, whilst later on, the hard numbers can be used to compare alternatives. Also another flexibility aspect should be included, namely the possibility to explore different scenarios (e.g. climate scenarios or different circumstances that are expected to happen with different probabilities). With this flexibility, the users can decide which scenario is reasonable to take into account. Still it must be possible to use the Explorer without adjusting these scenarios, so a standard scenario must be used to do the first calculations.

EASY FOR COMMUNICATION

Bart Bomas (2016), advisor spatial development at BVR advisers, that he and his colleagues could use the Explorer to explain complex information to laypeople. In a similar way, the Explorer could be employed during MLS brainstorming sessions to illustrate certain measures to the participants. For example, a brainstorm

session in April of 2016 included numerous parties (e.g. the Water Board, safety region, the municipality, the ministry, the province, and Directorate General for Public Works and Water Management). During this session, the participants explored possible spatial adaptation solutions to reduce the flood risk. Several participants did not know where the dike-rings were situated, which area would be flooded, or how high the water would rise in case of a flood. The lack of such information makes it difficult to think about concrete spatial solutions. Moreover, relatively few solutions were mentioned, and those that were offered were not particularly creative. In such situations, the Explorer could be of substantial use, as it could provide information, a list of potential spatial adaptation measures,¹⁴ and their main effects. In that way, the Explorer could support communication between parties.

SUFFICIENT INFORMATION

A last requirement that came forward in this research is the information that some potential users would like to see, but is not presented by the MLS Explorer. Mainly the private parties were interested in floods that are expected to happen more often, higher probability, but will have a lower impact. It was explicitly stated that is pluvial flooding would be take into account, they would be seriously interested in using the instrument.

¹⁴Other online instruments (e.g. the Climate App) offer similar information (see appendix C).

6

CASES ANALYSIS VIA THE RAKID MODEL

In the previous chapter, the spatial planning model was used to analyse the phases until the choice for an alternative. An important prerequisite of making a good choice is that the decision maker has sufficient knowledge about the alternatives and expected results of the different alternatives. This knowledge will be the central theme of the coming chapter. The analysis will continue with the same cases and start from the last phase of the previous chapter. Every choice for alternative was taken as starting point and subsequently the researcher analysed which knowledge and information were employed to make this decision. The analysis is structured according to the RAKID model, which was explained in chapter 2.3.2. This model is employed to structure the analysis of case study material. For each case, the action (decision) is first explained, followed by the knowledge used to make that decision, and the information used to gain that knowledge. After the knowledge and information is presented, it will be explained what information was used during the analysis and if this information is already presented by the existing MLS Explorer. If it is presented, then it was analysed how it was presented and if this was the best way or if it's better to present the information differently. If the information that was not presented by the MLS Explorer is listed in order to compare it with the other cases and after all four cases were analysed, decide if it should be presented by the Explorer.

6.1. CASE 1: CHOICE OF A LOCATION FOR THE EXPANSION OF ZWOLLE

In this case, the action was the choice for a specific location where to expand the city of Zwolle in Stadshagen.

Action

In terms of the knowledge that was used to make that decision, municipal workers used the reports discussed in chapter 5.1. In choosing that location, they were motivated by the fact that compared to the alternatives, the final site was home to fewer land owners, as the municipality needed to purchase property. The decision-makers had learned from earlier projects that that task is significantly more difficult when more land owners are present (van Beek & Vrouwe, 2016). In addition, it was considered easier to focus on 1 location with 8,500 dwellings, instead of on 2 locations with 5,000 and 3,500 dwellings, respectively (van Beek & Vrouwe, 2016, Personal interview).

Knowledge

In contrast to the other three cases, no flood-risk information was found in this case in either formal documents or (in)formal decisions (van Beek & Vrouwe, 2016, Personal interview). This does not mean that this analysis was not useful, since instances where such information could have played a role were still pinpointed, along with the actors that were involved at those moments. Access to flood-risk information would have been helpful at two points, namely: (1) developing alternatives and (2) comparing those options. During the development phase, four objectives were used to determine whether an alternative met the basic requirements. However, the team could have also required options to ensure that the flood risk would not exceed a stated value. In assessing or comparing alternatives, a flood-risk number could function as a single criterion instead of as a requirement, meaning that it could contribute to an overall score based on multiple criteria. This approach is comparable to the valuation matrix used in the comparison of the alternatives. That matrix could use the present value of the flood risk as a criterion. However, this input must only be used for an exploratory comparison and not the final analysis on which a choice is made.

Information

Table 6.1 offers a concrete example of information that could have been used. This information was obtained from the MLS Explorer by drawing the three locations on the map and generating the figures for the flood-

What?

risk scenarios. A complicating factor is that, to use these numbers, the user must know what they mean. For example, the expected yearly damage (last column) indicates the expected damage with currently existing probability of flooding and expected impact. If one of these two variables changes, the expected yearly damage will also change. Therefore, the location with the current flood-risk norm of 1/500 has a lower level of anticipated yearly damage than the location with a norm of 1/100, because damage is predicted to occur less frequently in the first instance. Therefore, the expected yearly damage under same normative situation (all 1/300 or all 1/100) would be useful for spatial planners. The present value of an alternative spatial plan could be added to this table to compare designs. A planner could experiment with several designs (e.g. increasing the building height or building waterproof dwellings) to get an idea of the effect on the flood risk.

Table 6.1: Figures obtained with the MLS Explorer for comparing three alternatives.

	Dike-ring	Current norm	Future norm	Expected damage [€/ha]	Expected victims [victim/ha]	Expected yearly damage [€/ha]
Stadshagen	10	1/500	1/3,000	2,59M	0.57	3,627 (if probability=1/500)
Herfte	53	1/100	1/3,000	2,57M	0.54	26,866 (if probability=1/100)
IJsselfront	53	1/100	1/3,000	2,00M	0.47	16,389 (if probability=1/100)

How? The information can be presented with numbers, as in Table 6.1. However, colours could also be added, with green indicating the best score, orange middling scores, and red the lowest scores. This information could also be displayed via a map. However, it is not currently possible to compare different locations in one session. If that were possible, each area could be assigned a colour, and users could see specific numbers as desired.

6.2. CASE 2: CHOICE OF A DESIGN FOR A SOUND BARRIER

Action The action in this case is the choice for the compartment rampart. In the report with the comparison of two alternatives it is literally mentioned that it delivers both knowledge and information ([projectteam Stadshagen & projectteam IJVD Zwolle, 2013](#), p. 4).

Knowledge A typical feature of knowledge was found in the documentation. The report recognised a lack of knowledge on the one hand, but on the other hand a lack of time and money to find data and transform it into knowledge. Therefore, the steps transforming data into information were skipped, and the selected alternatives were described on the basis of 'expert judgement'. In addition, the authors of the exploratory report judged that a flood from the IJssel would be associated with high inundation- depths and -speed, necessitating a large spatial reservation to protect the people. As such an initiative would be beyond the capacity of second-level measures, first-level measures were deemed necessary, and therefore, a flood from the IJssel was beyond the scope of the project ([projectteam Stadshagen & projectteam IJVD Zwolle, 2013](#)). The assessment of alternatives relied on knowledge regarding the costs and the risk for the regions inside and outside of the embanked area ([projectteam Stadshagen & projectteam IJVD Zwolle, 2013](#)). Those insights were accumulated over the years through experiences from other projects, allowing those with the required expertise to estimate the space required for a dike meeting the stated norms. Another expert judgement was reflected in the conclusion that an official dike would be significantly more expensive than an upgrade to a consequence reducing rampart. Finally, the exploration of alternatives used earlier studies as information input to generate knowledge.

Information During the brainstorming session, information and knowledge came together. Figures such as the number of potential victims and level of expected damage were given, and the participants were asked to think of measures to reduce those numbers. The brainstorming report included a map belonging to one of three discussed options, with information items like: ground level, locations of infrastructure, dikes, and possible compartment zones ([Enno Zuidema Stedenbouw et al., 2012](#), p. 38). One conclusion of the brainstorming session was that more information was needed about technical, financial, and feasibility aspects of the spatial compartment measures ([Enno Zuidema Stedenbouw et al., 2012](#), p. 31).

What? The below list summarises the information used to consider the flood risk in this case:

Items that the MLS Explorer currently presents:

- potential number of victims

- potential financial damage
- ground level
- present infrastructure

Items that the MLS Explorer does not currently present:

- present dikes
- number of dwellings in Stadshagen
- potential water depth inside the sound barrier
- potential water depth in dike-ring 10, located outside the sound barrier for scenarios with and without a sound barrier, and with floods from three different origins
- effect of waves caused by the wind
- local corridors in the sound barrier that have to be filled to keep the water outside the sound barrier
- locations where a sound barrier has not yet been constructed
- costs of both the dike alternative as the rampart alternative
- requirements for a dike
- requirements for a rampart

This list highlights several items that are not presented by the MLS Explorer. However, in certain cases, it would not be desirable for the instrument to present that information, as needs are context-dependent. However, others would be useful additions to the Explorer. At the end of this chapter, three such lists are compared to identify information that would be interesting to include in the MLS Explorer.

In this case, the above information was presented with maps and numbers in reports and tables. However, the final decision-makers were mainly briefed by the individuals who actually conducted the research. Those decision-makers then followed mainly the financial criteria.

How?

The sound barrier is currently being reinforced. To that end, it has been covered with clay and sown with special deeply rooted grass (Vergouwen & Lucas, 2014). These modifications will allow it to withstand water for a longer period during a flood, but the whole project is still under construction. An advantage is that the neighbourhood is also partly under construction, which has made it possible to combine these investments. However, the construction of such a project is often a slow process, and it often seems that a disaster is needed before rapid political actions can take place (Vrieling, 2016, Personal interview). Therefore, the north side of Stadshagen is not protected by the sound barrier, meaning that it would still flood if the primary dike were breached. The municipality is still brainstorming about the design of this last part of the sound barrier.

6.3. CASE 3: EXPLORATORY SEARCH FOR MLS SOLUTIONS

In the third case, the action was the decision to combine the three earlier compared alternative strategies ('zero victims', 'live with the river', and 'tamed river'). After the comparison it appeared that every alternative had its own strengths and weaknesses

Action

The report with an integral exploration towards water safety around the Meuse in Limburg (2011) is a solid example of gathering information from multiple sources and subsequently transforming it into knowledge. In other words, readers who understood the information in the report could acquire the knowledge needed to make decisions about potential MLS measures. The research has used some other reports (HKV,2010 DHV,2010 WPM,2010) to gain insight into the probability of flooding (Infram, CSO and HydroLogic, 2011, p. 31). The knowledge needed to choose the best strategy concerned the costs, benefits, advantages, and disadvantages of the individual strategies. A combination of initial costs and maintenance costs associated with the measures comprising the three strategies were criteria that scored negatively (the higher, the worse). The benefits were those criteria that received positive scores. For example, reducing the number of victims or the extent of the damage was positive, but a low level of technical applicability received a negative score (Infram, CSO and HydroLogic, 2011, p. 146-148).

Knowledge

The main pieces of information, which the report provided in numeric form, were the estimated damage and number of victims. Tables presenting this information can be found in appendix E. Furthermore, the presented information can be summarised as follows:

Information

Items that the MLS Explorer currently presents:

What?

- potential financial damage in different scenarios, calculated for different areas inside the dike-ring
- potential number of victims in different scenarios, calculated for different areas inside the dike-ring
- inundation depths at various points in time after a flood
- costs of the measures

Items that are not presented in the current MLS-explorer:

- vital objects in the area
- maintenance costs
- expected time between a flood prediction and the actual flood
- effects of a measure on nearby areas
- robustness in the case of extreme climate change
- space for natural processes
- public support
- technical feasibility
- expected realisation date

How? As already mentioned, most of these criteria used a scoring scheme of ‘-’, ‘0’, or ‘+’, with the expected damage, number of victims, inundation height, and prediction time numerically estimated. Some calculations with different software models that can predict inundation patterns, were employed in order to gain insight into this case. These inundation predictions were described and visualised with maps illustrating the flooded area at different points in time after a flood. The specialists who compared the different alternatives interpreted these maps.

6.4. CASE 4: SEARCH FOR NEW DEVELOPMENT IN VENLO

Action The action in the fourth case was not the selection of an alternative, as to date, only the first three phases (i.e., problem identification, problem analysis, and establishment of objectives) have taken place. Instead, the choice of these objectives represents the action. Multiple government bodies selected these objectives. The national government selected ‘strengthening the primary defences and implementing the area-specific sub-programme "Rivers" from the Delta Program’ and ‘conduction research towards spatial and infrastructural tasks around Greenport Venlo’. The municipality wanted to focus on improving water safety in Venlo and upstream areas, as well as on improvements of the urban structure via opportunities for regional economic development and spatial quality. These objectives are still quite broad and difficult to measure. Later in the MIRT process, near the plan development phase, these objectives will need to become more concrete.

Knowledge The phase of the MIRT process that this study analysed consisted of converging research towards a package of measures and preferred strategies. The reports that were written throughout the MIRT process reflect the process of gathering information to build knowledge. The end goal of the informal part of the process was to have sufficient knowledge to develop a strong areal agenda, which was the input for the start decision. The Note Promising Perspectives (Lievens CSO & BVR, 2015) stated the objectives for the pre-MIRT research phase. Three extreme scenarios were developed, with maps and textual explanations detailing the key points, advantages, and disadvantages of each. That report stated that knowledge was needed about all of these alternatives’ potential ability to reduce water levels. However, predictions of that nature are difficult to produce, since small changes can result in significant differences (Lievens CSO & BVR, 2015). Despite this difficulty, the report indicated which measures could have a greater (or weaker) effect on lowering the water level. In addition, the costs of individual measures were roughly estimated categorised in terms of high, low, probably inside budget, or investors had to be found. Finally, all measures within the three alternatives were qualitatively compared based upon six criteria (i.e., water level reduction, high-water safety, urban structure, nature, costs, and if the measures has a long-term or short-term perspective). This comparison was visualised in a table containing the 41 measures comprising the 3 alternatives. This approach allowed for a qualitative comparison of the alternatives (Lievens CSO & BVR, 2015, p. 52). Different information sources and knowledge were employed to give appropriate weights to the criteria. Due to these subjective weights, the outcome was also partly subjective.

Information The report by Lievens CSO and BVR 2016, which elaborated on the earlier Note Promising Perspective (Lievens CSO & BVR, 2015), offered more concrete details on the five hotspots, along with potential designs for each one. For each hotspot, the report contained a figure visualising the potential water level and

the future appearance of the area. Still, that approach simply offered an idea of how high the water might rise in extreme circumstances and did not offer actual numbers. The information used to develop these alternative designs came from a memorandum with calculations regarding spatial adaptation possibilities in several sections of dike-rings 68 and 69 (Terpstra & Leenders, 2016) and a document called Technical Factsheet Measures Preferred Strategy Meuse Limburg [Technische Factsheet Maatregelen Voorkeursstrategie Limburgse Maas (Maascorridor), 2015] (Lievens CSO & BVR, 2016, p. 21). A fact sheet¹ is a report offering information on, for example, costs, the effectiveness of measures, the locations of dikes, the size of the dikes, water levels (before and after a measure), ground-level differences, and soil types. Furthermore, several models were used to define expectations regarding damage, victim numbers, and the hydraulic effects of specific measures. Since the project was in an exploratory phase, these models were run with estimated figures (Lievens CSO & BVR, 2016, p. 21).

The main information came from several reports and served as input for the MIRT research report. The following list summarises this information:

Items that the MLS Explorer currently presents:

- expected water depth (m)
- expected costs of specific measures (euros)
- maximal water depth in case of a single dike gap (map with different colours for less than 0.5m, 0.5-2m, and more than 2m)
- expected victims (number of persons)

What?

Items that the MLS Explorer does not currently present:

- evacuation percentage
- number of dwellings in specific areas.
- existing critical infrastructure (yes/no, number, location)
- mortality in case of a flood (%)
- expected damage in 2050 (Euro)
- Costs of increasing the protection level 10 times (euros/km)
- expected water depth above the surface level at a specific location in case of high-water events that are expected to occur in varying frequencies (e.g. 100, 250, 2500 years)(cm)
- visualisation of the situation if measures are implemented (map illustrating which areas would—or would not—face consequences if certain measures were implemented)

The fact that this process is in an exploratory phase is reflected in vagueness of the information, such as the use of hand-drawn maps and rough estimations (e.g. the present number of houses in an area). This approach resulted in initial insights without making the claim of a high level of accuracy. Furthermore, several reports were used to base decisions. The researcher has participated in one meeting in which a brainstorming session was held about interesting measures. It was interesting to observe that several participants had to good insight in the actual situation and what different types of measures could mean for that situation. This brainstorm could have been more fruitful if there were maps available with different types of information like altitude or maximal water depth in case of a flood. Or if the MLS Explorer could have been used on a tablet in order to quickly explore the effects of different types of measures.

How?

This MIRT project was challenging to fit into the standard spatial planning structure, likely because of the size of the project. This project has a lengthy time frame, a considerable budget, and strict assessment criteria. Therefore, as early as the pre-MIRT research phase, studies have resulted in reports of varying levels of detail. The official report that served as input for the start-decision took the main conclusions from the studies regarding Venlo and merged them with other researches into a regional proposal towards the National Government (Programmateam Deltaprogramma Maas, 2016). The result was a positive decision, meaning that the process is now in the formal exploration phase. The final report of the informal process had seven appendices with all kinds of researches. In many of those studies, the MLS Explorer could have been interesting to use and several of those studies were beyond the scope of the information provided by the MLS Explorer and required specialists. However, later in the exploration phase, using the MLS Explorer might be relevant again. This utility at multiple moments illustrates the iterative structure of spatial planning processes.

¹The exact report was not available, but a comparable document was examined to determine what kind of information such a report typically contains.

6.5. CONCLUSIONS

The goal of this chapter was to answer the questions what information should be presented, and how this should be presented. From the analysis of the first case it emerged that no flood-risk information was used at that time. In the other three cases, multiple information items were employed to assess the flood risk. The researcher merged these three lists and analysed whether the MLS Explorer presents the information that was used in practice. Therewith, it was considered whether it would be interesting for the foreseen users to have that information displayed in the MLS explorer. Or if there was some reason why it was used in the case, but not interesting to add in the Explorer. In certain cases, an item was case-specific, meaning that it would have less relevance for a general instrument. The list with information that should be presented by the MLS Explorer is given in Table 6.2.

Table 6.2: List with all information items that should be presented by the MLS Explorer

Information item		Presented by the current Explorer	Explanation
1	Expected number of victims	yes	Interesting for many users, but could be presented in expected victims per 50 years instead of per year.
2	Expected financial damage	yes	This is presented by the MLS Explorer, but it should also present the possible deviation of the calculated number.
3	Potential water depth	yes	In case of flood risk, this is definitely interesting information
4	Elevation level of the area	yes	This is included in the Explorer, but the manner of presentation can be improved.
5	Size of a chosen area	yes	This gives a better impression for users who do not live near the area.
6	Probability of flooding	yes	Is included, but only the probability of an extreme flood. Many users are interested in (pluvial) floods that can occur more often.
7	Present value of expected damage	yes	Good information, but uncertainty in calculations should be added and users must have the option to adjust some initial assumptions.
8	Benefits of a measure	yes	It can be interesting to add non-financial benefits.
9	Benefit/cost ration of a measure	yes	This is the financial benefit/cost ratio. There can also be non-numerical costs or benefits.
10	Costs of possible measures		It is not estimated what a certain measure is expected to cost. This is good information for the planners since they gain a better picture of the costs and benefits.
11	Infrastructural situation		The planners would like to know which infrastructure will be affected by a flood. If this is known, both the costs -as a result of the loss of economic activities -and effects of non-passable escape routes can be estimated.
12	Dike-rings		Mainly in case of smaller dike-rings, it is interesting to show the borders of these rings. This gives an impression of where the flood will probably stop. And therefore where an alternative could be realised.
13	Vital objects in the area		The locations of vital objects like hospitals or electricity houses are valuable to know for a planner, since this influences the potential impact. Measures can be thought of to minimise this potential impact.
14	Expected prediction time of a flood		In case of a flooding from a river, this can be predicted hours or a day in advance. If this is the case, it can be sufficient to realise evacuation locations that are reachable within this timeframe. Or measures that can be build up within this timeframe.
15	Technical feasibility of measures		It can be that due to soil type or other characteristics, a specific measure is not feasible in specific location.
16	Expected evacuation fraction		The percentage of residents that is expected to follow the evacuation advice. It is debatable whether the planners need to anticipate upon these people.
17	Potential area that can flood during a flooding		This has overlap with the 12th item. If such an area is visualised, the planner has immediately potential fallback areas for its plans.

During this analysis, six categories of information were identified. These categories can be placed in a two by three matrix as shown in Table 6.3. The long list with all identified information items from the three cases can be found (Figure E.8).

Table 6.3: Table with six categories of information that were distinguished within the case study analysis

		Information is presented by the MLS Explorer	
		Yes	No
Information found during case study analysis in	Multiple cases	This outcome is seen as confirmation that the Explorer should continue to present such information	Such information would likely be interesting to be presented by the Explorer. Still, it has to be examined if its technically possible to add this information within the reasonable budget.
	One case	It can be questioned if this information should be presented by the Explorer	This information should be analysed in more detail to determine whether it is case-specific or relevant for flood-risk assessments in general.
	No case	A group of foreseen users of the Explorer should reflect on these items and decide whether they should be presented by the MLS Explorer.	Not interesting

Second question is related to how the information is presented, which is difficult to explain in one overview, but the interviews were useful to get to know better how the presentation can be improved to make the information more understandable and useful. An important point in this answer is that the presentation must be made more visionary, both of how a flood could look like and how the location could look like with certain measures. Several suggestion are given in Appendix F.

As in previous chapter, the conclusion of all analysed cases have been bundled in several requirements that should be met by the design of an instrument like the MLS Explorer. These requirements, of which four were also mentioned in previous chapter, are now explained in more detail.

ACCESSIBLE AND RAPID TO USE

In the second and fourth case we have seen brainstorm sessions with a variety of participants. During these brainstorm sessions it could have been really useful if an instrument like the MLS Explorer could have been used to explore the actual flood risk situation and get an idea of how different types of measures could influence that flood risk, and how expensive such a measure would be. Therefore it is essential that the Explorer is easy accessible via the internet and a users gets results within several minutes. Of course it can take longer if the Users wants to adjust several assumption to see how this influences its initial results.

UNDERSTANDABLE

One of the reasons that the MLS Explorer was developed was that the MLS Tool was difficult for municipal officials to use. Therefore, a more understandable instrument was needed. Nonetheless, many interviewees stated that they found the Explorer too difficult (Bomas, 2016; Enserink, 2016; van der Hagen, 2016; van Rijsen & Bruggink, 2016). However, an instrument intended for exploratory use at the beginning of the spatial planning process needs to be easy for potential users to understand and use. Both in the conclusions of the second case and an interview with Michiel van der Hagen (2016) it was found and mentioned that a system with traffic light would have been really useful to gain a quick understanding of the results. If it is green, there is no problem or the measures is really fruitful. If it is orange, there is extra research needed. And if it is red, the location has high flood risk or the measure is not interesting. This can be because of several reasons (e.g. it will not significantly reduce the flood risk, or it can be too expensive, or it is just not possible in that location.)

CREDIBLE

An interview with Arjan van Hal (2016), safety adviser at the water board of Limburg, highlighted a lack of credibility. The current Explorer treats the areas around Venlo as if they are outside of the dike, since long time ago there were no primary dikes and therefore the areas were not inside a dike. However, the dikes in Limburg that were built after 1995 have been primary dikes since 2006. Therefore, the Explorer has to perform the calculations as if the development is inside a dike. These small mistakes must be avoided, since they discourage users from returning to the Explorer, and may even result in individuals urging colleagues not to use the tool.

EASE OF COMMUNICATION

A distinction can be made between different types of projects. For projects such as moving dikes inland the MLS Explorer would not be suitable, as the topic is too specific. A specialist would need to perform a thorough analysis. However, the instrument can help in gaining initial insight, and it can perhaps even indicate whether hiring an expert would be worthwhile. When different parties are discussing potential options for a new harbour area (hotspot 4 of the Venlo case), they could use the Explorer to get an idea of the effects of certain measures. For example, if they have to choose between waterproofing several buildings or protecting the whole area from flooding, they might first want an impression of the associated costs, benefits, and damage and victims estimates. Further functions that could be added in order to make the Explorer suitable for communication (e.g. the function of printing the information in a standard template that can be compared with another case or added to a report or water paragraph in a zoning plan, or the ability to replicate information and subsequently adjust the initial assumptions to assess the effects.).

FLEXIBILITY

Just as in previous chapter, the results indicated the importance of flexibility. Namely, information must be presented in a flexible manner. While one user might be satisfied with colour-coded maps or numbers, another might want to know about the assumptions made to calculate the numbers (e.g. the discount rate or the soil type), as these can result in significant differences in outcomes. Users should be able to access such information by clicking a button or selecting an item on the main menu.

It is important to consider Spit and Zoete 2006's statement that 'Spatial planning processes follow a cyclical pattern, drawing on different inputs at different moments'. This structure is difficult to support with one single instrument (van Nieuwenhuijze, 2016, Personal interview). However, a more flexible Explorer could solve that problem to a certain extent.

SUFFICIENT INFORMATION

A variety of instruments are available, all with their own advantages and disadvantages. If one instrument can answer all stakeholders' questions, it would provide a significant added value. This would be more interesting than having to use several instruments for that one process. Therefore a total package of information is an important requirement for such an instrument.

Both literature and the interviews (Lodewijk van Nieuwenhuijze and Bart Bomas) underscored the iterative nature of spatial planning, the non-linear processes take a long time (Bomas, 2016; van Nieuwenhuijze, 2016). This is an essential aspect from this research that needs to be emphasized. Lodewijk van Nieuwenhuijze explained that spatial planning never follows a straight line, instead it follows a pattern with steps that are tending to repeat themselves, after several rounds this process has to result in a design worthy of implementation (see Figure 6.1).

The need of being applicable in an iterative spatial planning process is covered by the multiple requirements: Accessible and rapid to use, which makes it easy to perform new explorations with the newly gained insight. Flexibility, which makes it useful early in the process as well as later on with optional adjustments in the assumptions. Easy for communication, which makes it usable to explain other parties in the process how the suggestions result in a desired result. The



Figure 6.1: Iterations in spatial planning process, image was drawn by Lodewijk during the interview

7

PROGRAMME OF REQUIREMENTS AND SUGGESTED IMPROVEMENTS

In the last two chapters, several conclusions from the case studies were translated into requirements for an instrument that can assist spatial planners in assessing the flood risk. This chapter lists these requirements in a single programme and explains them in more detail. At the end of each requirement, the current Explorer is given a subjective quality score (very low, low, medium, high, or very high). This score was given by the researcher and is based on the responses and questions of the interviewees. At the end of the chapter, recommendations for an improved instrument are presented. The derivation of the requirement was explained in Chapter 5 and 6.

7.1. PROGRAMME OF REQUIREMENTS

The programme of requirements for an instrument, which can be used by spatial planners to assess flood risk, consists of six main requirements. For all these requirements it will be explained what is meant with the requirement, how this was found in the research, and a short example in order to explain what it concretely means and how it can be implemented in a design of instruments like the MLS-explorer. In the end of each requirement it will be mentioned what the 'subjective' score on a qualitative scale for the existing MLS-explorer is. This score is subjective since it is given by me, with the preceding research as knowledge background. The main purpose of the grade is to show which parts are most interesting to change in order to most effectively increase the quality of the Explorer.

1. The instrument should be accessible and usable in a short period of time. If a spatial planner can easily gain additional insight into the flood risk and related consequences in an area marked for potential development, he or she might be more likely to explore those factors at an early stage. After obtaining insight from the instrument, planners can then decide whether the location needs to change or whether restrictions are needed regarding the planned design. Therefore, the instrument must give useful results in within about 15 minutes, and it must be accessible in the average office without requiring special software. This high accessibility makes it also interesting to use it multiple times in the iterative planning process.

This requirement could be achieved in several ways, and this section does not offer a complete list. First, as mentioned before, accessibility via a web browser is helpful. Secondly, the user should only have to fill in the most important parameters that are essential for producing a rough estimation of the flood risk. Thirdly, leaving out certain functions may be preferable. Nonetheless, if the designers of the instrument decide to exclude a certain function, they should do so after considering whether certain users actually want that utility. To retain such users, the instrument should mention how to obtain that information via another instrument (e.g. the MLS Tool) and also provide a mailing address or phone number for those who want to learn more about how to obtain such data and about the associated costs.

A significant advantage of keeping a low threshold for using the instrument and only give a first rough indication is that it creates higher awareness among spatial planners, who can then choose how to react on the first insights. If it results in the conclusion that more detailed calculations are needed later in the spatial planning process, the planners would already have an approximate idea of the flood risk. If the threat is significant,

they would understand the urgency of conducting more detailed research. Likewise, knowing that the risk is lower would also be a valuable insight for the spatial planners.

The current Explorer scores quite highly on this requirement, since it is available via the internet and the user can obtain results in only few minutes. Still, improvement is possible, and therefore the Explorer's score on this requirement is on the border between medium and high, but on the side of high since it already gives a complete image of the flood risk.

2. The instrument should provide understandable output. In most cases, the user is not a flood-risk specialist. Therefore, the information must be presented in a manner that is understandable for them. This means using the terminology of spatial planners instead of the jargon of flood-risk specialists. The user's main task typically extends beyond considering the flood risk, and therefore, the results should be comparable with other criteria.

One way to make the information more understandable would be to improve its presentation. The instrument could present the output using more icons and maps instead of relying on numbers. For example, it could use an image with 20 persons per 100 years instead of a number like 0.2 victims per year. A substantial amount of information could be provided via maps instead of numbers, or perhaps both approaches could be used. Items like the probability of flooding, expected water depth, and type of surface could be illustrated on map with the location and coloured surfaces, and of course, with a complete legend. This visualisation would align with the exploratory purpose, since a specific location could be easily compared with the adjacent areas in the same figure.

Another concrete way of presenting information in a more understandable manner would be using a traffic light scoring system for MLS measures. For example, if the benefit-cost ratio is too low, a measure would get a red light, while higher scores would receive a green light, and uncertain ones would yield an orange light. Inside the light, the system could still present the number for users interested in concrete figures, but at the early stage of a project, in most cases, colours alone would be adequate. As stated above, the instrument must present information in a format familiar to spatial planners. Items such as the LIR [Lokaal Individueel Risico] and LSG [Lokaal Schade Gevaar] are often not understood. Instead, the programme should refer to the site-specific annual probability of a fatal flooding accident (fatalities/year), taking into account the evacuation possibilities instead of the LIR. Likewise, the annual probability of damage per euro present value (€/hectare/year) would be more useful than the LSG. In addition, terms such as 'primary' (area protected by primary flood defences) and 'regional' (area protected by regional flood defences) could be explained differently or supplemented with figures offering immediate clarification. Durk Riedstra (2016), who works for the organisation that commissioned the design of the MLS Explorer, stated that terms like 'risk', 'probability', and 'consequences' are not always well understood by spatial planners. It is important to take into account that not all spatial planners are flood-risk experts and therefore might use terms like 'probability' and 'risk' interchangeably. Furthermore, norms are often misunderstood by non-specialists. For these reasons, spatial planners sometimes struggle to understand the consequences of specific MLS measures.

The current Explorer could significantly improve in terms of presenting information in an understandable manner. Currently, its output is mainly comprehensible for users who already have a level of knowledge about flood risk, but not for the average spatial planner. That deficiency resulted in a low score in this requirement.

3. The Explorer should be flexible The case studies showed that the instrument has utility for multiple user groups. For this reason, its output should offer different levels of detail, because users differ in terms of their existing knowledge. This factor raises the question of whether meeting all users' needs is possible or whether different instruments should be designed for each group. In the researcher's opinion, if it were sufficiently flexible, a single instrument could satisfy all users. Another reason why the instrument should have a certain level of flexibility is to allow its use during different phases of the planning process, and also multiple times since the processes are non-linear. Analyses that were performed several months ago can lead to different outcomes if certain assumptions have changed.

This flexibility could conflict with the first requirement (i.e. accessible and rapid to use), and therefore, a balance needs to be found. Flexibility could be realised in different ways. First, both rough estimates and more

detailed information should be presented to meet users' diverse needs. More general information should be displayed first, with users clicking on specific fields to obtain further detail as needed. These fields could require more input from the user. A second aspect of flexibility is related to exploration. The option to try out different alternatives and immediately see their effect on the final outcome would be useful in that regard.

The system should be flexible with calculations from different scenarios (e.g. different water levels, which are the result of floods that are predicted to occur with different probabilities, also stated as different repetition times). This would make the tool more useful for private organisations. For instance, housing corporations do not care about events that happen once every 100,000 years, but they have a strong interest in events that can happen once every 10-50 years. Also, assumptions such as the discount rate should be adjustable so that users can evaluate the impact under different assumed scenarios. Lodewijk van Nieuwenhuijze (2016) mentioned that the ability to experiment with outcomes gives spatial planners an essential advantage, because such trial and error confers insight into the flood-risk situation. The unique characteristics of every location and plan also call for flexibility. Locations vary in terms of soil type and the type of flood risk, and plans can cover an industrial area, a leisure area, or—in most cases—a combination of several types of development. Therefore, the instrument should give users the option to select multiple characteristics. In a later stage, several of these characteristics should be adjustable to allow users to explore the flood risks in different situations. Users without detailed knowledge who do not want to play with the assumptions should be able to use automatically generated input values. Final results could be given with an uncertainty range. The more information that a user can provide, the lower the sensitivity of the outcome. This has to be stated explicitly for all outcomes. The second last point that should be more flexible is the discount rate, which is used to do the calculations, Durk Riedstra (2016) explained in the interview that at the moment of development it was already known that 5.5% was too high, but they were obliged to work with this percentage. It would be interesting if the user could adjust this in the end in order to see how this influences the results. The last aspect of flexibility concerns the measures. The instrument should give a long list of potentially interesting measures that could help to reduce the flood risk. Doing so would offer a broad picture of potential options to keep the flood risk beneath a certain level. It could even be the case that combinations might be the best fit.

For this requirement, much improvement is possible for the existing MLS Explorer. The only flexibility that it offers is the ability to set the boundaries of a certain area and to select a function. However, only one function is possible, and the tool cannot consider combinations of functions. The MLS Explorer thus gained a low score for this requirement.

4. The instrument should be credible An essential aspect of trustworthiness is the absence of mistakes. If a user explores a plan with the instrument and receives results that are obviously incorrect, he or she would be unlikely to use the instrument ever again. Another aspect of credibility is accuracy. The degree of accuracy should always be related to the precision of the input. If a rough estimation is calculated based on certain assumptions, the instrument should always present the range of error.

Credibility could be achieved by keeping calculation errors below an acceptable minimum and adding fields showing the range of error, or perhaps the option to click on the number to see the deviation. This requirement could be tested by asking specialists to draw a plan and filter mistakes from the results. The causes of these errors could then be identified and addressed.

Several calculations are made with multiple assumptions, and if all the uncertainties that go along with those assumptions are taken into account, the outcome sometimes has a quite large uncertainty range, and the instrument should mention that fact. When calculations rely on input with only one decimal place, a number with five decimal places should not be the result. Earlier in this report it was already mentioned that an incorrect calculation of the surface of an area had been rectified after it was noticed by the researcher. However, the current system still contains elements that can lead to incorrect results. The system uses map layers with a certain resolution level and influences the answer whether a location is inside or outside of a primary dike. If the user draws an area close to a dike that crosses a pixel located partially outside of that structure, the Explorer often classifies that whole zone as outside the dike. The reason is the low resolution or faulty coding.

These mistakes do not always occur; rather, they are specific to certain cases. Therefore, the Explorer's score for this requirement was medium, indicating adequacy but not a strong performance.

5. The instrument should be suitable for communication purposes. The current spatial planning process is more interactive than it was 20 years ago. This factor resulted in a requirement stipulating that the instrument should be suitable for communication purposes. More specifically, this section considers two types of communication: (1) oral communication (e.g. during brainstorming sessions or conversations) and (2) written communication (e.g. the water paragraph in a spatial plan).

There are multiple ways to make the instrument supportive of communication. For written communication purposes, the information could be presented in a standard template with the potential for regular use. Unique IDs could allow users to recall the results of a specific exploration. For oral communication, it is important that information be presented in a manner that is easy to read and discuss. In addition, presenting a comparison of alternatives might be highly interesting for usage in a bilateral or multilateral discussion.

A concrete example that would improve communication during a brainstorming session would be to give every project an ID number, allowing multiple users to work with the same input, and change certain assumptions to test the sensitivity. With that capability, the organiser of a brainstorming session could prepare a scenario in advance, or a municipal employee could ask the Water Board to look at a specific plan by providing the ID number. The added value for oral communication was identified during a brainstorming session in Venlo. During this session, the researcher noticed that many potential users were completely unfamiliar with MLS measures and their suitability under different circumstances. That lack of knowledge made it difficult to have a productive brainstorm session. The instrument could play a supportive role during such a meeting. The importance of written communication became clear after the interviews in the IJssel-Vecht region. In that area, municipalities are obliged to write a flood-risk paragraph. If the instrument could produce all the required information, preferably in a format that can immediately be merged with rest of the documentation, this would make the instrument highly useful for many municipalities. The specific report could also contain the project's ID number.

One function that is definitely lacking in the current Explorer concerns ease of communication, whilst the Explorer can really give added value when it provides input for negotiations or brainstorm sessions about new ideas. Currently, the Explorer is only usable for communication purposes if one party understands the system in such a way that that he/she is able to explain it to another person. However, as mentioned earlier, there is lots of room for improvement exists. Thus, the Explorer received a low quality score on this requirement.

6. The instrument should provide sufficient information for a decent flood-risk assessment. As a matter of course, an instrument helping spatial planners to assess the flood risk should give those users all the information they need for that task. A list of that information was compiled as part of the case-study analysis and is included in the last part of appendix E.

The information that the Explorer already provides could be tested by asking multiple spatial planners to use the instrument to assess the flood risk for a real project. Or just to use it to gain information for the writing of a flood-risk paragraph. If the user found any information to be lacking, that input could be passed to the system administrators, who could think about how to include it. That approach would result in a continuously improving instrument.

Some interesting examples of information that is interesting for the spatial planners are the locations of current dikes, the locations of vital objects, critical infrastructure with height of the roads and areas that would be flooded during different types of floods (and the probabilities of such events), the sensitivity or certainty of the results, or the expected warning time for a predicted flood. These items can be crucial for conducting a comprehensive flood-risk assessment, although the requirements depend on the location.

The Explorer already does a sufficient job of addressing this last requirement. The case-study analysis only identified a few items that would be interesting to add to the Explorer to obtain a more complete picture of the flood risk. For that reason, the current Explorer scores a high quality on this requirement.

CONCLUSION ON THE EXISTING MLS EXPLORER

When the programme of requirements is compared with the current Explorer, the Explorer scores quite highly on some points, although improvement is possible in several areas. A summary of the scores is given in

Table 7.1. This table demonstrates that in particular, improvements regarding flexibility and suitability for communication would lead to a significantly higher score, with comprehensibility and credibility also having room to improve. The remaining two requirements, accessible and rapid to use do not need much attention at present.

Table 7.1: The current Explorer's scores for the requirements on a scale from very low, low, medium, high, until very high

Requirement	Score
accessible and rapid to use	high
understandable output	low
flexible	low
credible	medium
suitable for communication	low
sufficient information	high

If all 6 requirements are given the same weight, the current Explorer has an average score just below medium. This result suggests that the current Explorer is lacking. This conclusion is in line with current usage figures (no significant usage), thereby implying that room exists for improvement. Table 7.1 expresses which aspects need most attention.

7.2. SUGGESTIONS FOR IMPROVEMENT

Drawing on the information gained during this research project, this section provides more concrete suggestions for a new instrument. This suggestion can function as inspiration for adjusting the MLS Explorer. In the researcher's opinion, these modifications could play a decisive role in determining the Explorer's usage rate. These suggestions are presented in a way comparable to the earlier explanation of the existing Explorer (see chapter 3.3). First, the main steps of the user interface are explained. Subsequently the IDEF0 scheme of the suggested instrument is given. Next, the main differences between the existing Explorer and the proposed tool are highlighted. To visualise the individual steps, the same approach used to illustrate the current Explorer (see appendix C) is again used. The visuals of how the instrument could look like after the proposed improvements were implemented can be found in appendix F.

The new, proposed Explorer makes use of eight steps, four of which are steered by the user (1, 3, 5, and 7) and four of which are produced by the system (2, 4, 6, and 8). Every step results in output that could be printed for inclusion in a flood-risk paragraph. The information that could be the result of every individual step is listed in the text boxes after the single step was explained. The information that is listed in these text boxes could be placed in a total report with the flood risks assessment in for that area. A visualisation of all steps can be found in appendix F.

1. Draw area of development. In the first step, the user draws the area of foreseen development.

2. Decide if the flood risk is significant. Next, the system uses data from multiple databases and map layers to calculate the flood risk in the specific area. The system answers several questions on a checklist to decide if it is necessary to continue the process in the MLS Explorer: What is the probability of a flood? What is the maximum expected depth of a flood? A programmed system then determines if there is a significant flood risk in the delineated area. If there is no significant flood risk, the Explorer concludes that further analysis is unnecessary. The user can print the initial results and use it as documentation to explain that the spatial plans are not significantly affected by the risk of a flood. Such a basic report can function as input for a flood-risk paragraph or the flood-risk part of a water paragraph. If there is a significant flood risk, the process continues in the third step.

Flood-risk paragraph part 1: flood risk

- Substantiated conclusion that the flood risk is not significant and therefore does not have to play a role in the spatial planning process (step 3a) or substantiated conclusion that the flood risk is (potentially) significant and has to be taken into account (step 3b)
- Map illustrating:

- the selected area (depicted on the map)
 - the surface of the area (numeric value)
 - existing dike-rings and their prescribed norms (map with dike-rings and their norms)
 - Existing vital objects, like a hospital or electricity house.[shown on the map]
 - Existing vital structures, such hospitals or electricity transformers (depicted on the map)
- Current estimated probability that a flood will occur ($<10^{-6}$, 10^{-6} - 10^{-4} , 10^{-4} - 10^{-2} , $>1/100$) presented both on a map with coloured area and in numeric form. Figures such as 10^{-5} are not easy to understand, because people live for perhaps 100 years, making 100,000 years hardly imaginable. Therefore, it is more useful to indicate the expected damage multiplied by the probability expressed in the estimated yearly costs.
 - Expected probability that a house, which stands for 50-100 years, will be harmed by a flood. ($<1\%$, 1 - 10% , 10 - 25% , 25 - 50% , or $>50\%$). Take, for example, a house situated in a dike-ring at Venlo, where the norm is prescribed at $1/300$. This means that for a dwelling that stands in that location for 100 years, there is 33% probability of it being flooded one time. If the value of the house is 200,000 euros, and the expected damage factor is assumed to be 50%, then the yearly expected damage is 330 euros. Using this format would be easier for spatial planners, municipal employees, and private parties to understand.
 - Map with potential maximum water depth in case of a flood (0-0.3m, 0.3-0.8m, 0.8-1.5m, 1.5-3m, or >3 m)
 - Prediction/warning/arrival time (<1 h, 1-6h, 6-12h, 12-24h, 2d, or >2 d)
 - Expected duration of the flood (day, week, month, or x number of months)

3. Select type of development.

If the system concludes that there is a significant flood risk, the process continues by letting the user answer several questions about the location and the foreseen development. For the location, it is important to know the dominant soil type, since this can make a significant difference in the costs of alternative measures. Dike strength is another key factor. During an interview, Arjan van Hal (2016), from water board peel & maasvallei mentioned that the soil type has significant influence and therefore should be taken into account. This can be taken into account by using a soil-type data layer inside the Explorer, or the user can pick the soil type. If the user does not have that information, the Explorer can instead use a standard average, with the user able to switch soil types to explore the differences. In addition to these areal properties, the user can also fill in the foreseen type of development, since that parameter can also make a large difference in the results. In the seventh step of the process, users can adjust these assumptions to evaluate the outcome's sensitivity to such changes.

Areal properties

- Dominant soil type (sand, peat, clay, bedrock, or unknown)
- Surface level and slope (sloping area, flat area on low ground, or flat area on high ground)
- Adaptation target (coastal flooding, fluvial flooding, pluvial flooding, or groundwater flooding)

Foreseen development

- Type of land use¹ (% single family houses, % apartments, % offices/shops, % industry, % utilities, and % park)
- Intensity (high/city centre, medium/suburban, or low/rural)
- Scale [(city, neighbourhood, street, or building)

With this input, the Explorer can calculate the risks and make a coarse separation between a wide variety of measures with the most potential. The existing soil type influences both the MLS measures that could potentially be implemented and their cost. The surface level, adaptation target, intensity, and scale predominantly affect the sequence of suggested MLS measures. Furthermore, the current Explorer only gives users the opportunity to select one type of land use, but this report proposes the option to mix types. As the case study revealed, a new development typically falls into multiple categories. The user can choose only one type of development, or spread the total percentage among different categories. In addition, a park category could be added to the list of development types, as Bart Bomas (2016) commented on its absence. If a user does not

¹The sum of the input always has to be 100; otherwise, the system gives an error message.

have more in-depth information, such as the soil type, he or she can check the ‘do not know’ option, prompting the system to use average or most likely inputs.

4. Calculate the risk. During this step, the system takes the user’s input from the first and third steps and calculates the risk. The output contains three fields: (1) damage, (2) risk, and (3) potential measures. The main difference between damage and risk is that damage output simply describes the damage that is expected to be the result of a flood, whilst risk also takes into account the probability of a flood, and spreads the impact over the years. This approach allows for comparisons with periodic investments to assess the level of acceptable costs for specific measures, since the costs should be in line with the expected damage. The last output item from this step is the potential measures, which are ranked in terms of their expected relevance. To create the ranking, a script (or programme code) that uses input variables (e.g. the potential depth, prediction time, soil type, elevation, and scale of development) should be written to order the measures. Certain output items, such as the expected water level, make more sense to display on a map, as that approach gives users clear insight into the larger area and to the option of moving the development to a comparable location with a lower flood risk.

Flood risk paragraph part 2: consequences and potential measures

- The potential damage is given for several flood probabilities (different repetition frequencies) in:
 - expected water level (first in a table and later in a map)
 - expected damage (table)
 - expected fatalities (table)
- The risk can be shown in a table with the:
 - yearly expected damage (€/year)
 - yearly expected fatalities (victims/year)
 - Present value of expected damage (€)
- potential measures
 - Varying list of measures with suitability score, arranged from most appropriate to least appropriate (image of measures with % scores)

The user can see the sensitivity of all numbers by clicking on them.

5. Choose most interesting measures. In the fifth step, the user chooses measures to include in further calculations by clicking on them (see Figure E8).

6. Determine effects of the measures. Next, the system calculates the effects and sorts the measures into categories: most likely worth the investment (green), potentially interesting but further research needed (orange), or most likely not worth the investment (red). This overview can be given for several assumptions, including the current situation and scenarios incorporating new norms.

Flood risk paragraph part 3: effects of the measures

- Expected cost-benefit ratio (numeric value)
- Estimated risk reduction (probability, impact)
- Estimated present value of a measure (€)
- Estimated reduction in terms of costs per victim (€/victim)
- Expected costs of the measures (€)
- Indicative benefits (spared victims, reduced damage €)

7. Change initial assumptions. By the seventh step, the user already knows the flood risk, along with the potential effects of several MLS measures. In this last input step, the user can explore whether the earlier assumptions have a significant effect on the results. If the user has no interest in this sensitivity analysis, he or she can click ‘show final report’ without changing any assumptions. As desired, however, the assumptions can be changed and the values recalculated with this new input. Users might want to change the following assumptions:

- Discount rate

- Climate scenario
- Soil type
- Economic growth
- Damage function (several damage functions are possible, and the choice of an option can result in significant differences in the results)

8. Recalculate the risks. Now after the optional recalculation, the changed output is provided in a table next to the initial output.

Flood risk paragraph part 4: effects of adjusted assumptions

- Only output variables that have changed due to the new assumptions are included in the table, which includes both the old and new values.

When all steps have been completed, the user can print the report, which contains the output boxes from steps 2, 4, 6, and (optionally) 8. They can use the printout for a flood-risk paragraph or water paragraph. Another important practical addition is the ability to save the input settings to easily recall a situation by providing a web link or ID number. Doing so allows one to immediately start where he or she left off. With this approach, the user can easily send the ID number or web link to another party. The web link is automatically printed at the beginning of the report.

MAIN DIFFERENCES

The main differences between the current Explorer and the proposed instrument are summarised in this section. The IDEF0 schemes in Figures 3.4 and 7.1 can be used to identify the differences in a visual way. The current Explorer has six steps (A1-1 until A1-6), with two that require input from the user. The proposed instrument has eight steps (A1-1 until A1-8), with four (potentially) requiring input from the user (average values used when information is not available). The main differences for each step are explained below, using the A numbers found in both IDEF0 schemes:

A1-1 No difference.

A1-2 No substantial difference. However, the new Explorer's process can end at this point when no significant flood risk is identified, and it presents information in a more comprehensible manner.

A1-3 The new third step is comparable with the current Explorer, but it gives users more options. The type of development can be indicated more precisely, and users can combine multiple categories. In addition, there are five more choices that users can make (soil type, surface level and slope, intensity, and scale of the development). However, the system can also use average values for those inputs, although the range of error is higher for that option.

A1-4 This step is comparable between the two tools, but information is presented in a more user-friendly manner in the new tool, allowing for more understanding on the part of users who are less knowledgeable about flood risks. The output is an overview of potential MLS measures and suitability scores based upon the input from A1-3.

A1-5 This step is different in the new instrument, because the current Explorer only presents the effects of a few preselected measures. In the proposed instrument, the user can select the most interesting measures from the large list presented during the fourth step. The main advantage of this addition is that it gives users ideas about MLS measures.

A1-6 Step A1-6 in the new instrument is comparable with A1-5 in the current Explorer, but it gives the effects of all the previously selected measures instead of the few measures that are given in the current Explorer. Again, the presentation is quite different, because the new instrument organises the selected measures into three categories (green light, orange light, and red light). In addition, the uncertainty of every calculation is explicitly given with the results.

A1-7 This is a new step that allows users to change the initial assumptions and explore the effects of those alterations.

A1-8 Another new step, A1-8 illustrates the differences in outcomes due to the adjusted assumptions. The new tool replaces the function of A1-6 in the current Explorer by printing a report. Now the whole overview can be seen in three or four paragraphs, as was shown in the earlier text boxes.

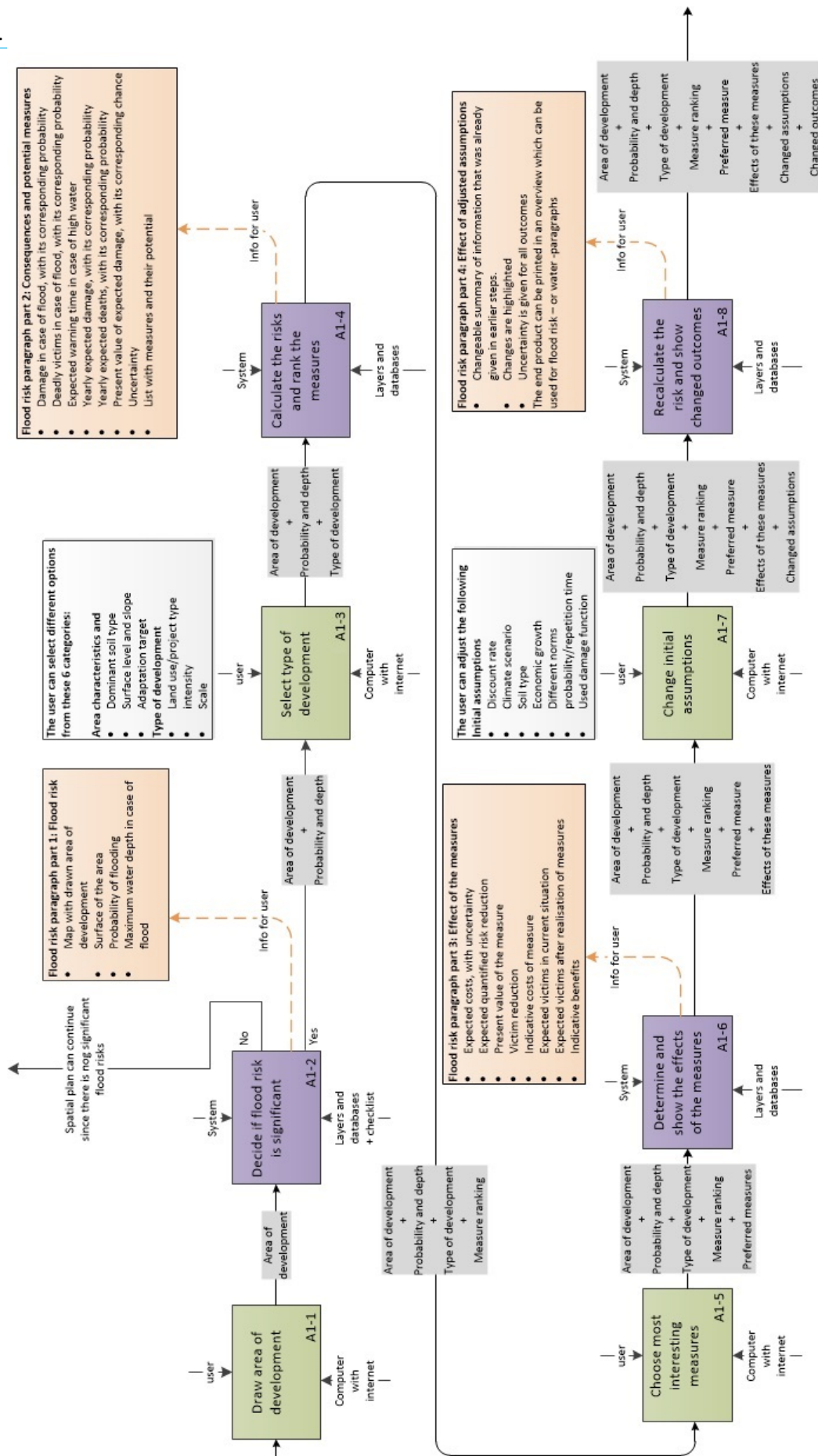


Figure 7.1: IDEFO scheme with all steps of the proposed MLS-explorer 2.0

8

CONCLUSIONS AND RECOMMENDATIONS

8.1. CONCLUSIONS

Returning to where it all started, the central objective of this research has been to first develop a programme of requirements and then assess if and how the existing MLS Explorer might be improved. The programme of requirements developed via the research contains six key points:

1. Be accessible and rapid to use
2. Provide understandable output
3. Be flexible
4. Be credible
5. Be easy to use for communication purposes
6. Provide sufficient information for a decent flood-risk assessment

The rest of this concluding chapter is structured around the sub-questions.

Sub-question 1: When should the flood risk be assessed during the spatial planning process? The MLS Explorer adds the most value in the following phases of the spatial planning process: problem analysis, set objectives, develop alternatives, and begin to compare alternatives. It is still suitable at later stages of the actual assessment, but the MLS Tool is expected to be more useful at that point. Also the Problem identification can be little bit useful, since the MLS Explorer can help to identify the problem, but most of the times the problem has a different background (e.g. population growth). (see Figure 5.12). The Explorer can play an exploratory function in these early phases. Specifically, in exploring the problem, it can indicate the expected water depth and maximum damage after a flood, and it can also state the probability of such an event. On the basis of such an exploration, planners can create targets for the maximum damage per year or maximum number of victims. During the development of alternatives, it can be used to shape the options and exclude those that score poorly on the flood-risk requirement. Later, it can be used as a further criterion to compare full alternatives or individual measures. All of these actions take place close to the beginning of the process. Important aspect of the spatial planning process are the iterations, which means that the Explorer can be useful in several moments in for a different purpose. This was covered by the requirements of accessible and rapid to use, being flexible, and easiness for communication purposes.

Sub-question 2: Who are best suited for conducting an exploratory flood-risk assessment? The MLS Explorer has the most potential for local government bodies, such as municipalities and water boards. However, private parties could also be interesting to take into account. More centralised government organisations, such as provincial and national government bodies, appreciate it when other government officials use the Explorer, but they are not first in line to use it themselves.

Sub-question 3: What information should the instrument present? The information that the current Explorer presents is already useful, however it can be improved. The instrument should present all information that is needed for a first rough flood risk assessment. These are given in Table 6.2. Some are already in the Explorer others should be included in order to give a total insight into the flood-risk situation. This is a first list from one research, therefore it would be wise to test this list with foreseen users of the instrument.

Sub-question 4: How should the information be presented? The exchange of flood-risk information represents an important form of communication that leads to more flood-proof spatial plans. Transforming information to knowledge was found to be the main obstacle in that process. A spatial planner needs knowledge to make the right decision, but to gain that knowledge, he or she must first understand information.

That understanding can be reached by presenting information in a format that is comprehensible for spatial planners. That means presenting it in a more visionary way that is familiar to them, rather than in a manner designed for water managers. The water managers like numbers to perform calculations, but many spatial planner do prefer maps with colors and object that represent a certain meaning.

Sub-question 5: How does the current Explorer score in terms of the newly developed requirements? A programme of requirements consisting of six requirements was used to assess the current Explorer. The current MLS Explorer scored quite well on certain requirements, but there is still room for improvement for others. These minor adjustments would represent a small step for the designer but would add substantial value to the MLS Explorer. Table 7.1 lists the tool's subjective scores for the requirements. This table should only be used to gain an impression of how the current design could be tested. For a more comprehensive assessment, potential users and experts should evaluate the tool. If for now the assumption is made that the requirements all have the same weight, the scores in this table result just below medium. Both 'accessible and rapid to use' and 'sufficient information' score high and don't need lot of attention. 'credible' gains a medium score and should be improved to make the Explorer more trustworthiness. In the end the requirements 'understandable output', 'flexible', and 'suitable for communication' have a low quality score can result in the biggest difference in quality of the MLS Explorer. Several suggestions for improvements are given in chapter 7.2.

Sub-question 6: How can the current Explorer be improved? There are several ways that the Explorer could be improved. The most interesting improvements can summarised in: (1) making it easier to use for the spatial planners, (2) make it more flexible to be usable in different phases by different users, (4) making it credible, and last but not least (5) make it suitable for different forms of communication that is already used in the realm of spatial planning. Some examples of how this improvement could be realised can be found in chapter 7.2.

8.2. RECOMMENDATIONS

This research resulted in a long list of potentially interesting recommendations, but this section only explains those that are especially urgent, easy to implement, or impactful.

The first recommendation is that Deltares or GGPWWM [RWS] should find out if provincial governments are willing to use an adjusted MLS Explorer when writing a flood-risk paragraph. As mentioned in the IJssel-Vecht case, these paragraphs are mandatory to write during the development of new spatial plans in the province of Overijssel. The writer of such a text currently must consult at least five instruments providing information similar to that offered by the MLS Explorer. When provinces are interesting in using the Explorer for such paragraphs, this can result in a new budget for further development.

Such further development could start by testing the Explorer in a few provinces and adjusting it as needed before introducing it as a standard instrument for the national water test. Besides Overijssel, the province of Utrecht also requires a flood-risk paragraph, and Noord-Holland is working on such a requirement. Besides this, the Delta Programme 2015 report has mentioned the new instrument(s) supporting water boards and DGPWWM [RWS] should be developed to transparently visualise and calculate changes in the water system. The current MLS Explorer already is a good starting point for improving this visualisation and calculation. A study could analyse multiple water tests and flood-risk paragraphs, propose adjustments for the MLS Explorer, and then discuss these with a group spatial planners and flood-risk managers with experience in that domain. Based on the outcomes of that discussion, the programme of requirements could be adjusted to make it suitable for this new instrument. The main advantage of the existing MLS Explorer is that it gives participants in brainstorm sessions concrete examples and helps them to determine their preferences.

The second recommendation is to remove (technical) mistakes. If the Explorer makes an error while a user is trialling it, the mistake could lower confidence in the Explorer, perhaps to an irreparable extent. Thus, the first priority should be to solve the problems mentioned in this report. Next, Deltares should verify with a small group involved during the design stage that the initial goal has been reached, that the programme of requirements suits that goal, and that the initial target is still desirable. In addition, the Explorer should also be validated. That process might entail letting a group spatial planners and flood-risk experts discuss the quality of the Explorer and suggest other information for inclusion. Or perhaps spatial planners could experiment with the Explorer on their own territory and provide feedback on whether its results were representative.

The last key recommendation is to validate the programme of requirements listed in this report. Spatial plan-

ners and flood-risk specialists should discuss these prerequisites, adjust them as needed. This can be done in two questions, (1) the Explorer should be given a score upon every single requirements, and (2) the question can be stated how important every single requirement is compared to the remaining requirements, and give it a weight factor. With the answers to these two questions the designers of Deltares and HKV can concretely improve the Explorer such that it gains a better score.

FURTHER RESEARCH

Further research could pursue five key subjects of interest. First, researchers could analyse whether the Explorer could be made suitable for flooding caused by precipitation, or whether a comparable instrument for that particular purpose should be developed. The topic of extreme precipitation is gaining attention due to the intense weather events triggered by the changing climate.

A second topic of new research is the market in foreign countries. In those countries, such flood risk assessment is even more interesting, since there generally is a lower basic safety level. Since the safety level is lower, it will be earlier interesting to implement measures from the second or third level of MLS. Furthermore, in regions with greater elevation differences, MLS measures may have even more potential. Such a study should investigate the spatial planning processes in those countries, examining how they compare to procedures in the Netherlands. In addition, the governmental structures and parties involved in spatial planning might be different, water boards are typically Dutch institutions.

In the same vein, the third recommendation is to expand the number of Dutch cases, because qualitative research has its downside. This study only interviewed a small number of respondents, most of whom had a certain relation to water management. For this reason, the interview findings are not representative of the whole country, and it could be interesting to analyse several other cases. Such an analysis could result in more clearly defined requirements and new ideas for further improvements to the Explorer. The results from this research could be used to structure such research, as this study has already indicated which phases would be interesting to analyse and which parties could be interviewed.

The fourth recommendation is to find out if the Explorer could be optimised for redevelopment, instead of only for new neighbourhoods. Again, the results may indicate that a comparable instrument for that purpose should be developed. This difference between new neighbourhoods and redevelopment makes a significant difference in costs, and redevelopment happens more often than new development projects.

The last suggestion concerns the potential private market for an adjusted MLS Explorer. The time perspective of the tool would need to change, since such users are mainly interested in shorter time spans. A housing association in the IJssel-Vecht region has already demonstrated interest in risk statistics, such as the present value. In connection with this recommendation, a study on the potential market for the Explorer could be conducted. Different parties, including housing associations, Inter Provinciaal Overleg (IPO), and Vereniging Nederlandse Gemeenten (VNG) could be interviewed to gauge their interest in investing and their requirements for such an instrument. Another interesting organisation with which Deltares should establish contact is Landelijk informatiesysteem Water en Overstromingen (LIWO). This organisation supplies information about water and floods via a range of instruments. Perhaps the MLS Explorer could join that list.

8.3. REFLECTION

This section gives the reflection in three categories. The first upon the content of this research, the MLS Explorer. The second is upon MLS concept, which was the initial reason to develop the MLS Explorer and seems to have lost political support in the last years. And the third reflection is upon the whole research process.

RESEARCH CONTENT

MLS-explorer: The results of the MLS Explorer should be received as a rough estimation that can give a first insight. It is not a tool that presents highly accurate calculations. If the instrument advises negatively about a potential MLS measure, that outcome should not immediately stop users from thinking about new measures, especially when the range of error is high. Instead, the results must viewed from a more relative perspective, and the instrument is intended to stimulate fruitful discussion. This can be realised by using the green/orange/red light scheme for 'certain potential', 'possible potential', and 'no potential'. Furthermore, by clearly explaining the uncertainty related to the model's assumptions. If the new Explorer's second step (A1-2 in Figure 7.1) ends the discussion, a certainty that no significant risk is present should be the reason. When the outcome is inside a range of uncertainty, this should be noticed, and the Explorer should proceed with

step A1-3.

Moreover, technical designers should keep in mind that it can sometimes be necessary to consider a situation from another perspective. In this case, the user's perspective is of relevance. If an alternative measure is not significant or is implicitly taken into account, the Explorer should still display those findings, since users do not have the same knowledge as designers. One interviewee wanted to see a comparison of levels 2 and 3 with level 1. One of the designers responded that level 1 measures are designed to maximise benefits relative to costs, and so the cost-benefit ratio would equal 1. While designers have that knowledge, users do not, and so the instrument should provide those numbers to easily allow comparisons.

This research has explained how the MLS Explorer could be adjusted to help to fill the expertise gap between information and knowledge. However, the leverage gap between knowledge and action is likely equally important, and politics play a key role in that regard. If there will be several flooding problems in the coming spring, more funding will be available for these kinds of instruments.

DIKAR or RAKID model: As I have explained in chapter 6, the DIKAR model is not the best way to approach the design of an instrument that has to support decisions. If a designer used this approach, the probability is high that it will result in an instrument that is not being used since the user doesn't see the value of it. Therefore the DIKAR process needs to be preceded by the result driven RAKID approach. This is explained more elaborated in the research paper in chapter.

Scientific relevance of the results: The results of this research are mainly practical for the company where I did my graduation project and other companies that design comparable products. The main aspects that is relevant for further research and therefore show the scientific relevance of this study, is the need for more research towards cooperation between spatial planners and water managers (flood risk managers in this research but should be taken more widely in further research). In our contemporary environment of climate change and growing demand for housing this is becoming more important. And the main aspect that is interesting within this topic, is the information exchange and especially the way in which information is presented from one actor to another. This is a field of knowledge in which still a lot of benefits can be achieved.

MLS CONCEPT

As regards MLS, first, politics is always an important factor in the use of such concepts. Durk Riedstra (2016) from DGPWWM [RWS] mentioned that several years ago, MLS received considerable attention, but that nowadays, the trend has reversed. However, he sees changes and the potential for critical infrastructural developments, such as hospitals and facilities supplying electricity or drinking water. Therefore, MLS may attract more attention in the future. In my opinion this MLS should be presented more as an added measure instead of a replacement of the existing flood protection. This is similar to the robust development to reduce potential impact as was explained in Table 3.2.

SELF-REFLECTION ON THE RESEARCH PROCESS

To start this self-reflection I want to mention that it was difficult for me to follow the 'standard canvas' of doing research. I am a person who likes to think out of the box, if everybody does in a specific way, I ask myself the question, can I do it differently? With the goal to reach a better result. In order to work this way it is hard to first come with a solid plan with questions and theoretical perspectives that steer the way in which the desired goal of the research can be reached. In my research I started with the practical part of analysing the instrument and the potential users, after an evaporative analysis of these aspects, I started to search for theoretical models that describe the same problems as I identified in the beginning of the research. From that moment on I started to structure the rest of research and already gained results along these two theoretical models.

When, in the end, I look back on my research process and read through the feedback of my graduation committee, I realise that I have learned a valuable lesson about the how use of scientific methods, and I start to wonder what the result would have been if I had known this in the beginning.

The main lessons that I learned during this research can be summarised in four points. The first concerns how to structure research in the absence of a predefined scheme. Doing such a whole project for the first time was sometimes quite difficult, and I have learned that simply taking action and making adjustments as

needed is more beneficial than spending a long time thinking about the best possible move.

Secondly, talking with others about one's research can have several advantages. Other people can offer ideas, and listening to these proposals is important, because many readers are likely to have the same thoughts. These thoughts can be mentioned and explained, with an emphasis on why an idea is incorrect or beyond the scope of the research. Furthermore, even if a principle is obvious for the writer, it can be necessary to explicitly state that idea in the report. In addition, trying to explain an idea to someone who is not active in the same research field can provide insight into how to simplify the description.

Third, I found it interesting to see the value of ex-post research, which can provide clarifying insights of value for new projects. I think that I underestimated that value before my thesis project.

The last lesson, which I did not learn during my research but in a meeting of the High-Water Protection Programme 2 (HWBP-2), is that it is (almost) impossible to reach the perfect situation due to the time it needs to realise a chosen solution. During the meeting from the HWBP-2, a participant explained that perfect insight into a system is impossible, if only because the full spatial planning process takes a long time. That time period entails changes, and so the situation after implementation differs from the situation during the period of analysis. All that one can do is strive for the best result and remain open to making changes due to new circumstances.

What I would do differently the next time: I would adjust many small elements if I were to carry out a similar project, along with two main aspects: First, I would approach people for interviews or conversations at an earlier stage. At the beginning, I tried to be perfectly prepared, but perfectly prepared is not possible in an interview. Knowing the answers beforehand is impossible, and the interviewer must be able to focus on the important points in the specific interview. To prepare for the interviews, I compiled a long list of questions. However, during the interviews, the conversation automatically moved towards the most interesting aspect for the specific person. I improved this method of interviewing substantially in the final interviews. Secondly, I would change my approach to the writing process. Instead of just starting to write, I would spend more time on first developing a solid structure, even if it added several extra days. That approach would save a significant amount of time in terms of making corrections or changing parts of the text at later stages. From a slightly different perspective, this waiting with writing must stay in equilibrium, since one knows more at the end than at the beginning.

The cooperation among disciplines, aimed at achieving the best possible result, has always appealed to me. My study path reflects that preference, as I started with technical studies, focusing on mechanical engineering, later moved towards policy management, and then returned to a more technical course via civil engineering. This interest in multiple areas was essential in my search for improvements for an instrument aiming to bring together the realms of spatial planners and flood-risk managers. As I reviewed the literature, I noted that these two realms, which both have a long history in the Netherlands, are slowly merging. I enjoyed the chance to dive deeper into this subject, which personally interests me. My attraction to the subject had a small downside, since it sometimes resulted in me getting lost in interesting articles not directly linked to my specific research topic.

As I conducted this study, I found it remarkable that MLS is a well-known concept within the realm of water specialists, while the larger Dutch public is pretty much unfamiliar with the idea. That lack of knowledge is one origin of the problem analysed in this research. In other words, a significant amount of work remains to be done.

There are many lessons that can only be learned outside of the lecture hall. An important lesson that I learned through my whole graduation project as a whole (in terms of both content and process) is that although working with others can be complicated, it can yield better results in a shorter amount of time. At moments during my graduation project, I needed to talk with my fellow students before I saw a solution, and it sometimes helped to simply tell my story to someone else.

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SKETCH OF ENVIRONMENTAL -AND FLOOD RISK -POLICIES THAT HAVE IMPLICATIONS FOR SPATIAL PLANNING

This appendix gives an overview of important political changes in the last century, with most attention for the period from 1970 and beyond. This gives an impression of how the realms of water management and spatial planning merged towards each other. Most interesting part for this research is the explicit recognition for the need to manage potential impact of flooding, with spatial planning measures. This was done in the beginning of the current century ("Anders omgaan met water", 2000). The overview in this appendix contributes to the changes mentioned in chapter 1 and to the road towards Multi-level safety and rapprochements of the realms of spatial planning and water management in 3.

- **1916 Zuiderzee-flood** [zuiderzeevloed]
The Zuiderzee-flood caused 19 deaths and was the main reason for development of the Closure-dike.
- **1927 Start of the construction of the closure-dike**[Afsluitdijk]
The closure-dike is a dam, which closes the Lake IJssel from the Wadden Sea. The construction of this dam started in 1927 and was finished in 1932.
- **1945-1952 Recovering period after second world war**
After there was second world war ended in 1945 the quality of the Dutch coastal defences was not on the political agenda because of other priorities, like rebuilding devastated cities and lots of houses.
- **1953 The great flood** [de Watersnoodramp]
In the night of 31 January to the first of February 1953 a heavy storm surge in combination with a spring-tide caused The great flood, which took 1836 victims in the Netherlands. After this flood a higher political ability resulted the design of a defence system, named the Deltaworks [Deltawerken], to protect the south-western part of Netherlands against flooding. It exists of 14 dams and flood barriers and started in 1953, only 20 days after the big flood disaster. The whole project was finished in 1997).
- **1953 First Delta Commission**Deltacommissie
On 18th of February 1953 the first Delta commission was established in order to advise the minister about the measures that were needed to prevent a great flood from happening again.
- **1957 (first)Delta Act(Delta wet)(entered into force in 1958)**
This law served until 2005 (when it was adopted by the Law on the flood defences). It introduced the maximum norm frequency that served as requirements for the design flood barriers.
- **1960 Report of the first Delta Commission**
The final report of the first Delta commission was published, but already several barriers of the Delta-plan were already finished or being build.
- **1970 Fast growing resistance against closure of Ossterschelde estuary** Around the early seventies, the public began to show resistance against ecological and aesthetic degradation of the delta and river landscape caused by the Delta Plan.

- **1974 Adjustment of the Delta Plan**
In 1974 it was decided that the Oosterschelde barrier had to be designed with sluice gate doors, which are normally open but can be closed in case of a storm.
- **1985 Environmental impact assessment**
After the second world war, the planning was mainly based on technical feasibility and economic viability. During the seventies this has slowly changed and resulted in an European Directive(85/337/EEG, this Directive is several times adjusted and currently known as 2011/92/EU). This Directive aims to take environmental impact of new plans into account in the beginning of a project. In 1987 the Environmental Impact Assessment is an official instrument in the Netherlands.
- **1993 High water situation**
In Venlo the water came until 18.35 meter above NAP due to a water discharge of 3,120 m³/second, with in the whole Netherlands 12.000 evacuations and 250 Million guilders damage (47M in Venlo).
- **1995 High water situation**
In Venlo the water came until 18.46 meter above NAP due to a water discharge of 2,870 m³/second, with in the whole Netherlands 250.000 evacuations and 150 Million guilders damage.
- **1996 Beleidslijn Ruimte voor de rivier**
Two ministers(V&W and VROM) published that the recent high water situations in the Meuse and Rhine, the vulnerability of the Netherlands, the unfavourable expectations about climate change and sea-level rise result in the necessity of durable protection against high water situations. In this document it is explained that not only the dikes will be enforced or heightened, but also more room for the rivers will be realised.
- **1998 Heavy rainfall in the autumn**
This rainfall caused lots of damage in the southwester and north-eastern part of the Netherlands. The damage payments went up to 690 million guilders.
- **1998 fourth note water management (Vierde nota waterhuishouding)**
The fourth note water management is focused on a safe and habitable land and maintaining of healthy water systems. It mentioned the new insights in topics like climate change, sea level rise and soil subsidence. And it explained the necessity for good cooperation between the water-, environmental- and spatial planning -policies. This fourth note was succeeded by the national water plan in 2009
- **1999 Notitie Aanpak Wateroverlast**
The ministry of Traffic and water affairs [Verkeer en Waterstaat], Union of Water boards [Unie van waterschappen](UVW), and the Interprovincial Consultation[interprovinciaal overleg](IPO) published a note in which they proposed measures to address the growing problems of water nuisance.
- **1999 Commissie Waterbeheer 21^e eeuw**
In april 1999 the Commission Waterbeheer 21^e eeuw (Tielerooij) was installed. This commission had the task to advise the government how to deal with water in the changing climate of the 21th century. Their report was published in 2000 and main points were that water must be dealt with differently and more space should be reserved.
- **2000 Anders omgaan met water**
The water policy had to change due to the increase of high water in the rivers, nuisance due to intensive precipitation and the accelerated sea level rise. In this report is was stated that a big chance is needed in the water management. The spatial planning should aim to reduce the potential impact of flooding.
- **2001 Start-agreement "Waterbeleid 21^e eeuw"**
On 14 February 2001 the national government, IPO, UVW and Dutch municipalities association [Vereniging Nederlandse Gemeenten](VNG) signed this agreement, which states that the water test from that moment on will be applied
- **2001 Administrative memorandum water assessment**
In the administrative memorandum water assessment [Bestuurlijke notitie watertoets] gives substance to the implementation of the water test. Since it is a new test, it is also explained how it has to be used.
- **2003 Nationaal water management agreement**
The national water management agreement [Nationaal Bestuursakkoord Water] is a subsequent step after the start-agreement "Waterbeleid 21^e eeuw". It emphasizes the joint responsibility for getting

the total water management in the right state, it explains which instruments have to be used in order to realise certain tasks, and it explains how different parties are responsible for different tasks. This agreement was signed by VNG, IPO, UVW, and the Association of water companies in the Netherlands [Vereniging van waterbedrijven in Nederland] (VEWIN) with the goal to collectively realise sufficient protection against flooding, good quality water and sufficient fresh water.

- **2005 Veiligheid Nederland in Kaart (VNK)**

In the beginning of the 21st the Dutch government recognised the importance of deeper analysis towards the impact of a flood, instead of mainly focussing on the probability. In 2001, a collaboration between DGPWWM [RWS], provinces and water boards were instructed to analyse and subsequently map the flood risks in in the Netherlands.

- **2006 Start of programme adaptation space and climate**

In this National Programme Adaptation Space and Climate [Nationaal Programma Adaptatie Ruimte en Klimaat] the National government sets climate proof spatial development high on the political agendas. There are three tracks formulated that have to help making the spatial development more climate proof, track 1: awareness, networking and strategy development, track 2: development and disseminating of knowledge, and development of a joint vision, track 3: develop tools, advise on measures and stimulate innovation.

- **2006 Beleidsstraject waterveiligheid 21e eeuw**

This policy trajectory was started in 2006 and is continued in the Delta programme safety [Deltaprogramma veiligheid] Results of this project were presented in a Delta decision water safety [Deltabeslissing Waterveiligheid]. Core of this decision is the newly proposed norms, which will be implemented on the first of January 2017. The objectives of the new norms are twofold: First, basic safety for everybody in the Netherlands, this is translated in a minimal level of protection of 10^{-5} per year. Second is the impact reduction by extra preventing large groups of victims and high economic damage. Inc with large groups, high economic impact or vital and vulnerable infrastructure of national importance should be even higher.

- **2007 Flood directive**

The European Directive with the aim to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. ([European Commission, 2007](#)). This European Directive had to be implemented by all European members. This has resulted in a preliminary risk assessment, flood hazard and flood risks maps and flood risk management plans.

- **2008 Report Second Delta commission**

In September 2007 the national government installed the Delta-commission "Commissie-Veerman" with the task to give an advice on how to protect the country against consequences of the changing climate. The concrete question was: how the Netherlands could be developed such a way that it will be protected against flooding and an attractive place to live, work, recreate and invest. The Delta-commission did twelve recommendations of which two are interesting for this research. The "safety level" and the "New development plans" . Both have a role in Multi-level safety, they can respectively be put under the smart combinations approach and the robust development to reduce impact as described in table 3.2.

- **2008 Nota Waterveiligheid 21e eeuw**

The note water safety 21st century gives a summary of activities that were, since 2007, performed in the frame of water safety 21st century. These activities had the purpose to give an answer to the policy questions on the field of impact reduction during a flood. This resulted in several policy options, which could function as foundation for further decisions. within the theme Watersafety and spatial considerations the following two policy questions were central: 1. how can the relation between water safety and Spatial development decisions be strengthened. 2. which physical measures have high potential in damage reduction. These two questions have led to different policy options: exposure reduction, vulnerability reduction, and risk zoning as foundation for impact reduction in spatial development.

- **2009 Water Act [Waterwet]**

In 2009, eight laws have been merged into one new Water Act [Waterwet]. This law regulates the management of surface water, groundwater and improves the relationship between water management and spatial planning. In addition, it provides an important contributions to governmental objectives such

as reduction of regulations and the administrative burden. The water act will stay in force until the new surroundings-law that is currently expected to become active in 2018.

- **2009 National Waterplan** [Nationaal Waterplan]
The Dutch government makes every 5 years a new water plan. This plan presents the main points of the national water policy and the parts of the national spatial planning policy that is linked to the water policy. This is one of the European requirements that result from the Water Framework Directive(2000), Floods Directive(2007) and the Marine Strategy Framework Directive (2008). Important point in this first National water plan is that for the first time the new approach of Multi-Level safety was presented.
- **2010 Installation of the first Delta Commissioner**[Delta commissaris]
In this year the Delta Commissioner "Wim Kuijken" started as commissioner. He is responsible for the yearly Delta programme and main government commissioner who represents the water management in the Netherlands. In 2011 the function of Delta commissioner was official established in the Delta Act [Deltawet].
- **2010 Delta programme 2011** [Deltaprogramma]
Since 2010(First Delta programme for the year 2011 was presented in September 2010) The Netherlands presents every year a Delta programme in which the plans to protect the country against flooding and to secure freshwater supplies are drawn. The main goal of this programme is to make the flood protection, freshwater supply and spatial development in 2050 climate resilient and water robust. This first programme presented nine sub-programmes that are based on the 12 recommendations from the second Delta commission. The most important sub-programmes for this research were "Safety and " " New development & restructuring", Just like the earlier explained Delta-decision these two sub-programmes can respectively be put under the smart combinations approach and the robust development to reduce impact as described in table 3.2.
- **2011 Delta Act**
The first of December 2011 the Water Act and Act infrastructure fund were amended because of the flood protection and the care of freshwater supply in relation to the expected climate changes. This resulted in the new Delta Act. The earlier Delta Act from 1957 was mainly aimed for closure of estuaries and enforcement of flood barriers, this law was written to serve specific projects. The new Delta Act is different, it has no concrete projects but it officially settles the function of Delta commissioner, and in regulates the Delta Fund as a financing programme for the Delta programmes. This way every year approximately one billion Euro is reserved for flood prevention and freshwater measures.
- **2014 Deltaprogramma 2015**
This Delta programme is specifically interesting because of five Delta-decisions, which came forth from the nine sub-programmes of the first Delta programme. The two most important are "Water safety" and "Spatial adaptation". These two decision again can be placed under the two columns of table 3.2, and represent different way of approaching Multi-level safety. The first(Safety) is aimed to reach the norm, if possible with a combination of all three levels. The second is mainly focused on the second and third levels, and assuming that the norms are already realised. But still with spatial planning choices the impact can probably be reduced without significant higher costs, you could say a more flood risk conscious way of spatial planning.
- **2014 VNK2 report**
The project "National Flood Risk Analysis in the Netherlands (VNK) started in 2006 and finished in 2014 has put the ideas of the second Delta Commission (2008) into practice. It stated that the flood protection had to change from reactive response to proactive protection. In order to do this in the best possible manner, first the whole country has been subject analysis, which resulted in insight into the reliability, weak points and potential damage. This has also resulted in the availability of basic information for political and administrative decisions about the needed investments to reach the desired level of protection. Some important insight that were explained in this report are: a dike can already fail before the water flows over it, the possible impact of a flood differs significantly within and between different dike-rings, the soil type is very important for the strength of a dike, for reliable calculations of flooding probability it is important to have correct information, and with the collected data and results, the effects of measures can be made understandable quite easily. All this has resulted in important input for improvement of the Dutch flood protection policy. Last important sentence in this report was that "*Optimum collaboration between central government, water authorities, provincial authorities, en-*

gineering consultancies and research institutions will be vital to ensure that the Netherlands remains the best protected delta in the world"([Havinga, 2014](#)).

- **2017 New norms**

The first of January 2017, the new norms will come into force. These new norms are based upon a risk approach, which means that there is more attention for the value behind the dike (impact) instead of almost purely the probability that the dikes will be swamped. The difference is shortly described as a change from probability of exceedance towards flood probability, meaning that the probability of a flood is calculated taking into account a larger number of fail mechanisms, which all have their own weight factor.

- **2018 Environment Planning Act** [Omgevingswet]

Currently the Dutch government is hard working on a new Environment Planning Act. The current expectation is that it will come into force in 2018, and it will change a lot in the Dutch system of spatial planning. It is still not really easy to foresee all the changes, but few things that can be stated are: The main content of the Water-Act will be included in this new law, and therewith lapse. One of the main ideas is that this Act will make live easier with clear interrelationships and eye for sustainable development. This is again a good example of a new enforcement of the link between two realms of water management and spatial planning.

B

SPATIAL PLANNING PROCESS

This appendix shows seven different ways in which the spatial planning process is described in different ways. All contain between 6 and 9 separated steps. From all these types, a general type of spatial planning, containing six steps was distilled. These steps are explained in chapter [2.3.1](#)

1. Problem identification
2. Problem analysis
3. Set objectives
4. Develop alternatives
5. Compare alternatives
6. Choose one alternative

This structure was used in this research to analyse the case studies with use of the spatial planning model in chapter [5](#). The models that were found in several books identify between six and nine phases in a spatial planning process. It will be shortly described how the six steps were distilled from the 7 models that placed next to each other in [Figure B.1](#).

Despite one, although implicitly analysis of threats can also be interpreted as problem analysis, all first steps are described as problem identification or problem analysis. So the first step is taken as problem identification.

Secondly there are some differences, since five of the seven models more or less state that the next step is found in defining the objectives, and two state something like analysis of the problem. This seems a good step before stating the objectives. So the second step is Problem analysis.

As was already seen in the former step, the setting of objectives is logically the next step.

The fourth step can be found in the third, fourth, and even fifth step of the analysed models. I gave it the name 'develop alternatives' but it can be found under comparable names like designing solutions, designing, generate, alternative plans.

The fifth step contains the comparison of the previously developed alternatives. This is also found in different forms mostly in with the term ex ante evaluation, but also as comparing of alternatives of just comparing.

The last step that was identified for this research is the choice of one alternative. This can most of the times be found in the last step, however sometimes there is also a action or ex post evaluation added. Important note in here is that action can be interpreted in different manners, making a choice or actually implementing the plan. In this research the implementation of the plan is outside the scope so it was interpreted as taking a decision.

	Dynamisch cyclisch planningproces	cyclisch planningproces volgens Chapin en Kaiser	cyclisch planningproces van Hickling (blz 123 Roo & Voogds 2004)	Ruimtelijke ordening in the Netherlands
1	probleemsignalisering	problem definition	scanning	probleemidentificatie
2	bepaling van de structuur van de problemen	objectives	shaping	doelstellingen
3	ontwikkelen van alternatieve oplossingen	solutions searching principles	designing	generatie
4	vergelijking van de alternatieven	design of long and short range solutions	comparing	evaluatie (ex ante)
5	bepaling van de onzekerheden	evaluation	choosing	uitvoering
6	keuzen van de te nemen maatregelen	action	doing	evaluatie (ex post)

	Conventioneel/lineair planvormingsproces (blz. 121 Roo & Voogd 2004)	planvormingsproces binnen een dynamische beleidscontext	Doelgerichte oriëntatie van planning
1	probleemanalyse	probleemanalyse	analyse van kansen en bedreigingen (OT)
2	doelstellingen	doelstellingen	analyse van sterke en zwakke punten (SW)
3	alternatieve plannen	verkenning bekend beleid	selectie van doelgroepen (wel/niet-gebruikers)(wel/niet-gevestigden)
4	planevaluatie	inventarisatie instrumentarium	verkenning van doelgroepen
5	voorkeursplan	alternatieve plannen	aanpassing van het fysiek-ruimtelijke aanbod
6	inspraak/overleg	planevaluatie	
7	definitief plan	voorkeursplan	
8		inspraak/overleg	
9		definitief plan	

Figure B.1: Seven different descriptions of the spatial planning proces next to each other. These have been used in chapter 5 to analyse the four cases

C

THE MLS-EXPLORER

All steps that have been described in chapter 3.3 are now visualised with screen shots. This will give a better impression of the current Explorer. It can also be used as very primitive tutorial for working with the Explorer. In the end of this chapter also a small comparison with other instruments is given. This was used as inspiration to find good improvements.

It all starts with opening an internet browser and type www.mlvverkenner.nl in your address bar to start the MLS-explorer, you get the screen in figure C.1.



Figure C.1: First screen with explanation of the MLS-explorer, what it presents, by who it was developed and who commissioned it, click "Start MLV verkenner"



Figure C.2: Short explanation of how the Explorer works, click ">"

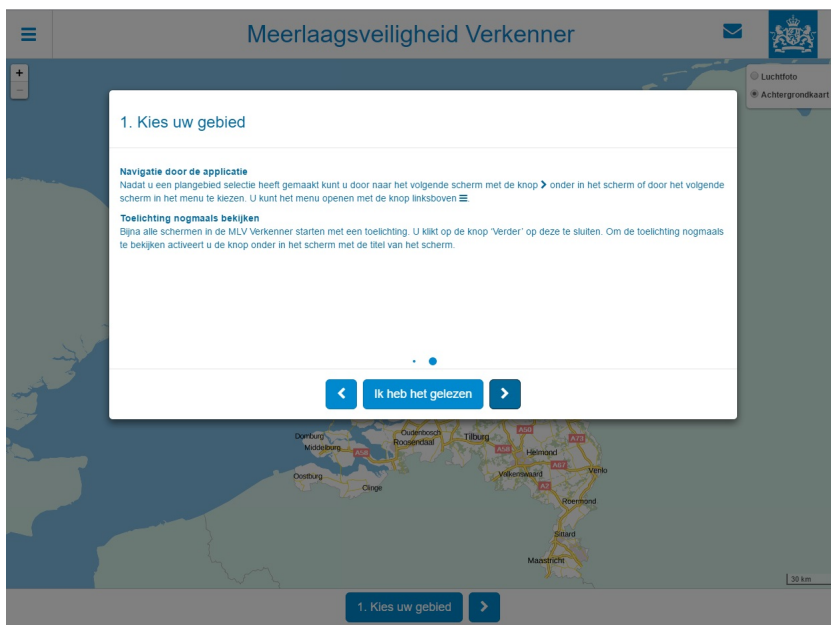


Figure C.3: Explanation how the user can open the main menu, click "Ik heb het gelezen"



Figure C.4: The user can open the main menu that shows the six steps by clicking the three blue bars in the upper left corner. It furthermore gives the opportunity to open a tutorial, read more information about the instrument, and send feedback. Now in order to start with the first step, zoom in to the foreseen location of development with the scroll button on your mouse or the "+" in the upper left corner

STEP 1: CHOOSE YOUR AREA



Figure C.5: As shown in this figure, the background is switched from map [Achtergrondkaart] to satellite image [luchtfoto]. The location which is used in this example is close to the city of Zwolle, the user can now select the small pentagon in the upper left corner and start drawing the foreseen area of development



Figure C.6: The user now draws a closed area, after the closing the area by clicking the first whit dot again, it closes. If needed the user can change the area by clicking the small pencil in the square underneath the pentagon



Figure C.7: The users can always open the main menu and go back to previous steps. The present step is arced white.

STEP 2: VIEW YOUR AREA

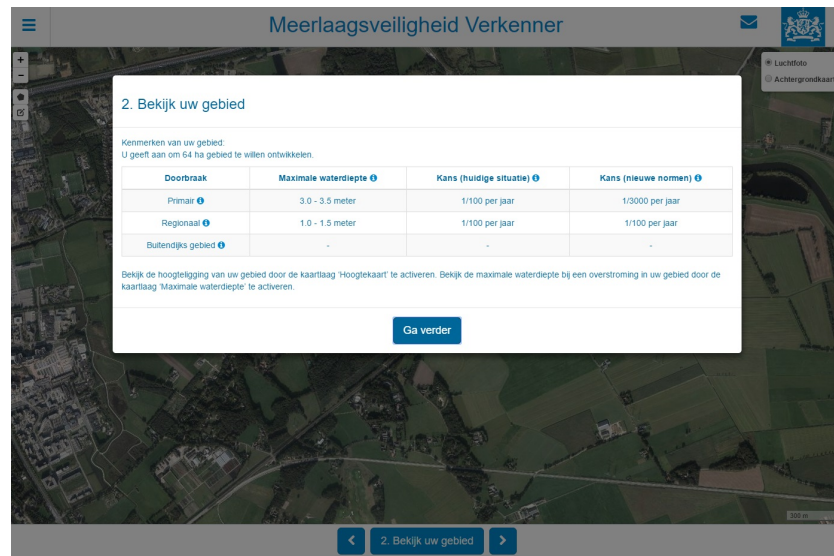


Figure C.8: table after area of development was drawn, now the users clicks "Ga verder"

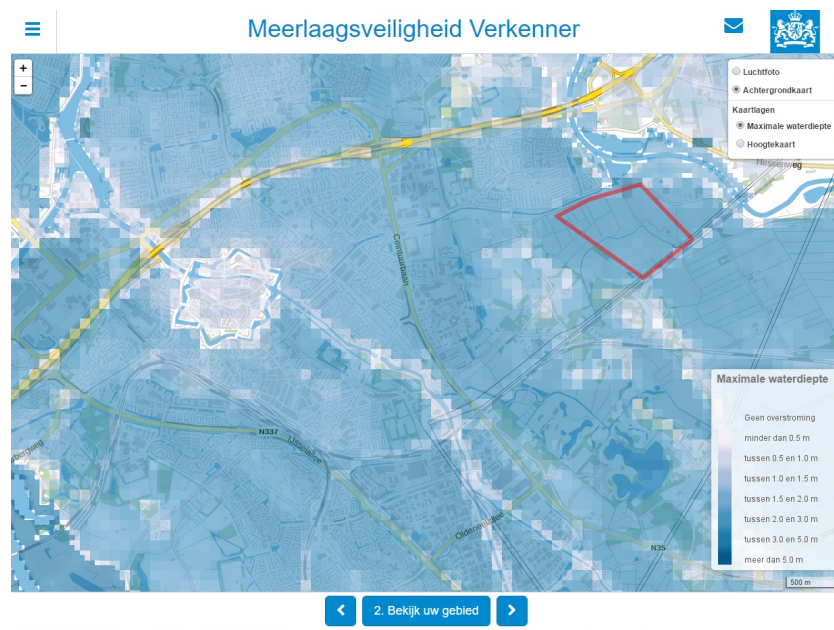


Figure C.9: After clicking "ga verder" the user can zoom in and out, change between satellite image or map and see the maximal water levels or altitude in the area



Figure C.10: Now the user sees the altitude map, the legenda must be scrolled down to seen the level, it is around NAP

STEP 3: CHOOSE YOUR DEVELOPMENT

The third step is just choosing a type of development

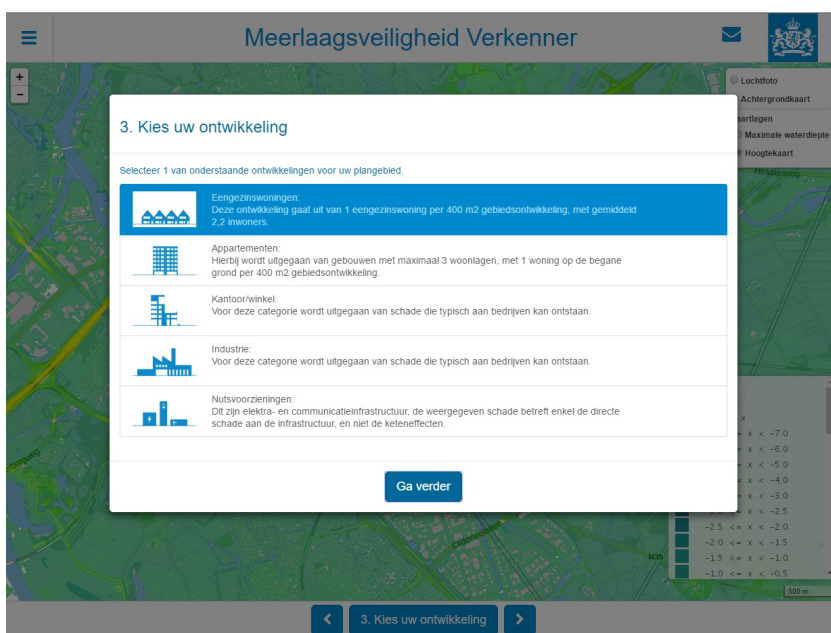


Figure C.11: In this figure you can see the possible type of development, the users picks one and clicks "Ga verder"

STEP 4: SHOW RISK IN THE AREA

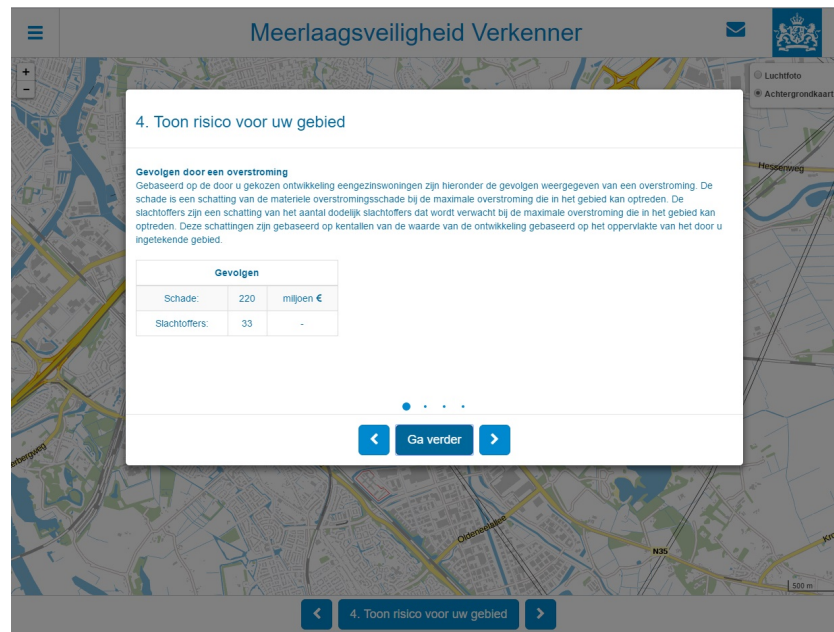


Figure C.12: In step 4, the Explorer first shows the expected financial damage and the expected victims

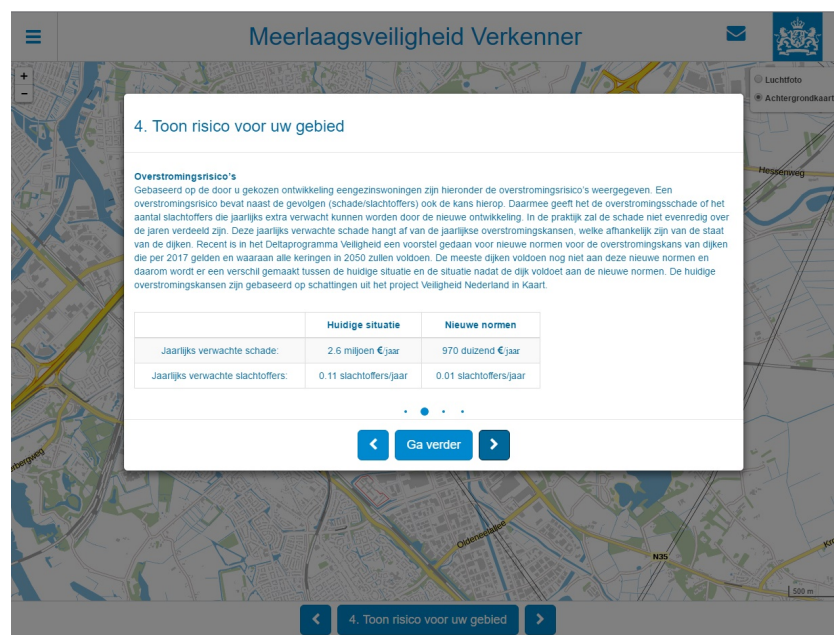


Figure C.13: After clicking ">" the user gets to see the yearly expected financial damage and the yearly expected victims the current situation and if the area meets the new norms

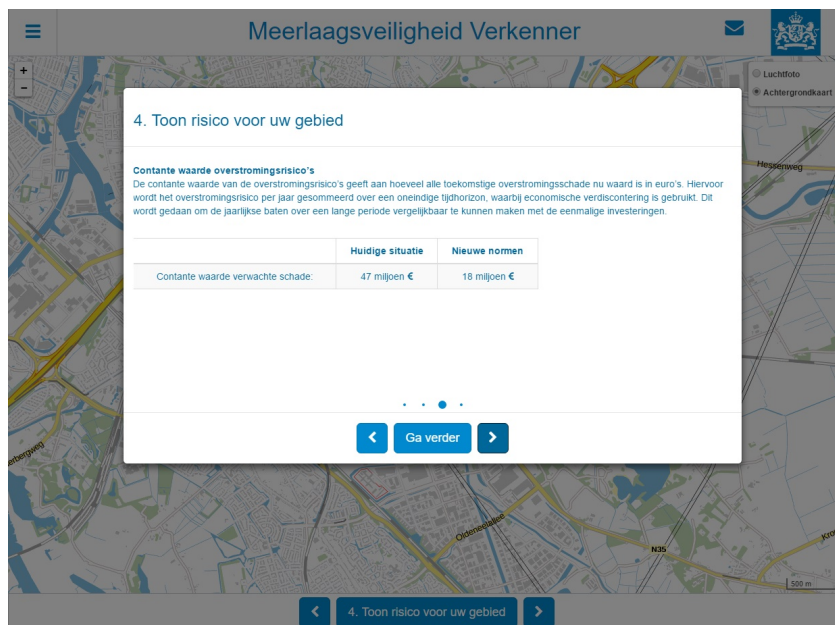


Figure C.14: The last number in step 4 are the present value of the expected damage is given for current situation and after the area meets the new norms. This number is easy to compare with the costs of a measure.

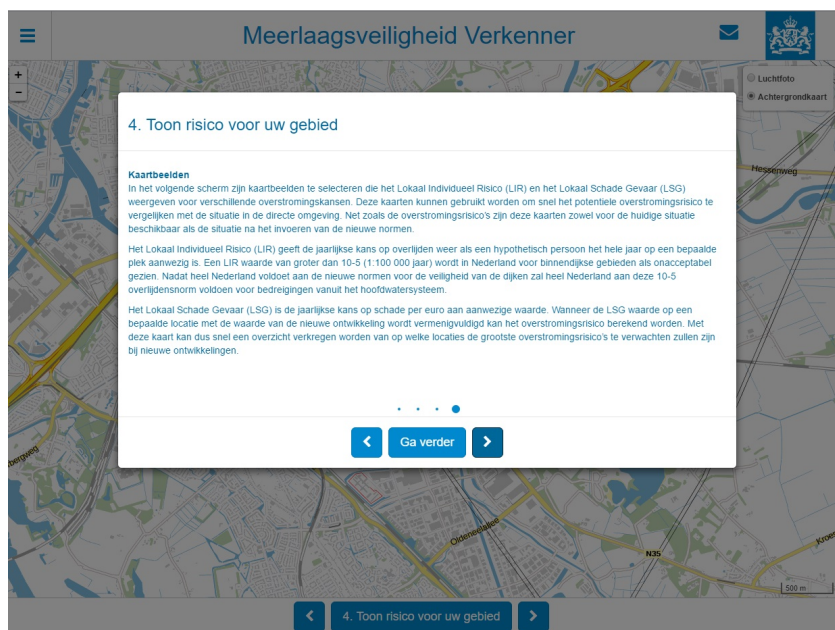


Figure C.15: The Explorer shortly explains the meaning the terms Lokaal Individueel Risico[LIR] and Lokaal Schade Gevaar [LSG]

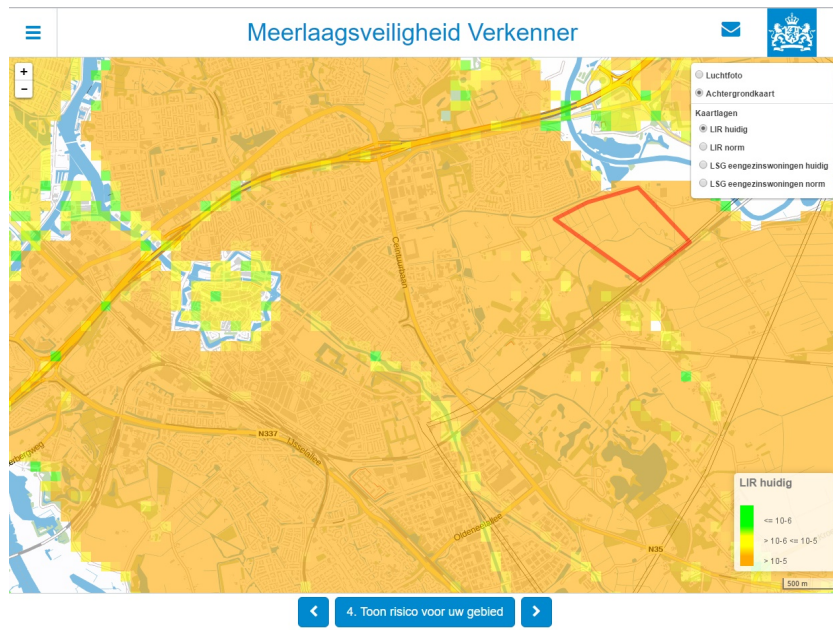


Figure C.16: LIR can be visualised in a map with colours for three ranges of yearly probability

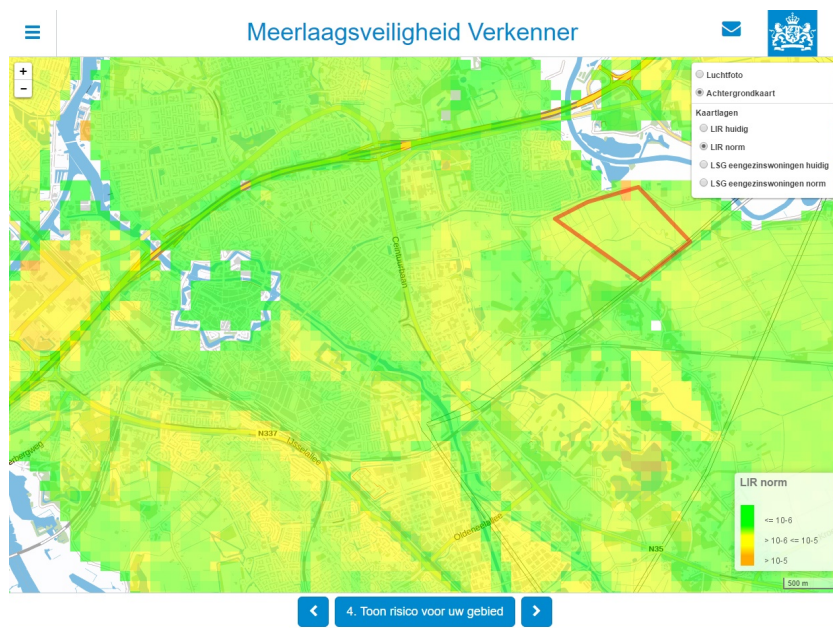


Figure C.17: The LIR-map can also be viewed for the case that the new norms have been realised

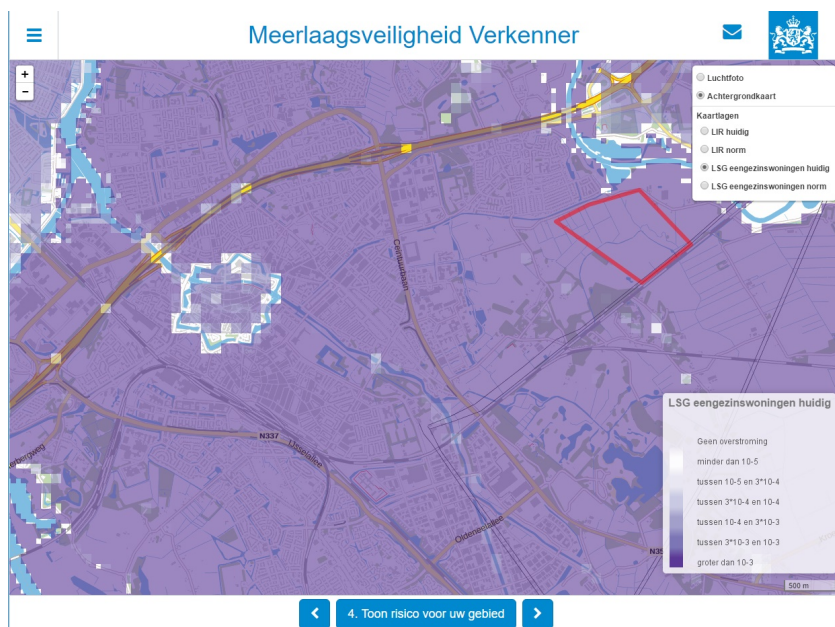


Figure C.18: LSG-map for the current situation

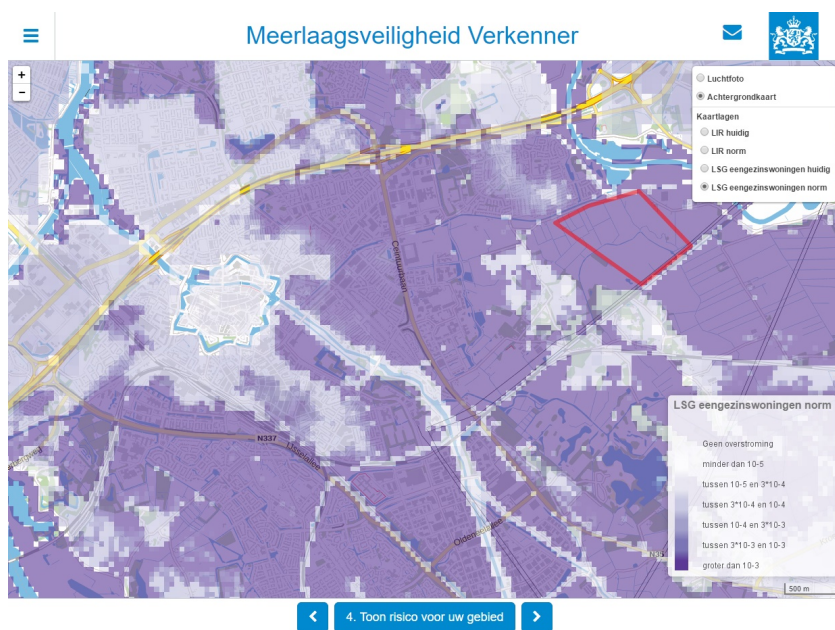


Figure C.19: LSG-map in the case that the new norms have been realised

STEP 5: SHOW EFFECTS FROM POSSIBLE MEASURES IN THE CHOSEN AREA



Figure C.20: First step in step 5 is a menu that explains the information that will be given for all possible measures in the next step

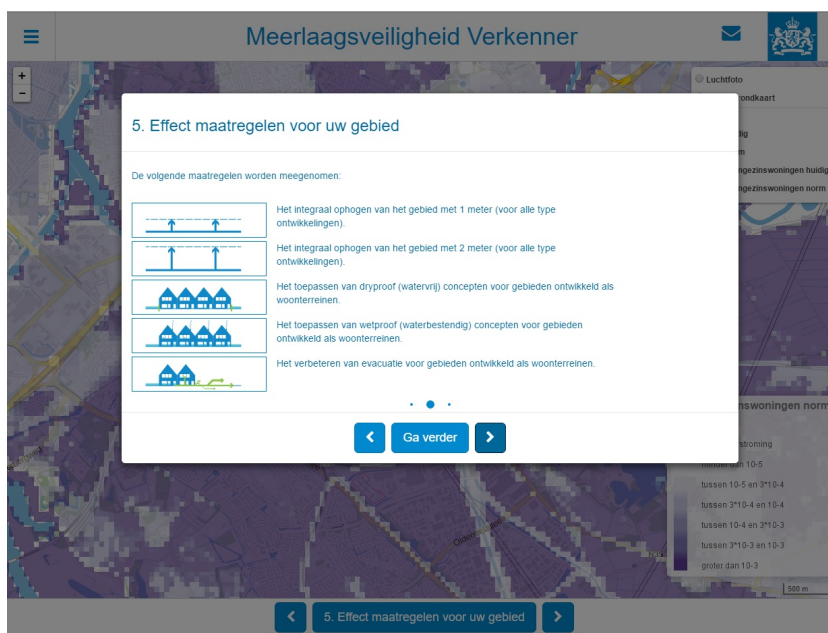


Figure C.21: Now the Explorer explains the five measures that are analysed in the exploratory search for interesting MLS-measures



Figure C.22: Here the Explorer explains that measures differ for damage reduction and victim reduction. And it explains that the user can select the measure in order to see detailed information.

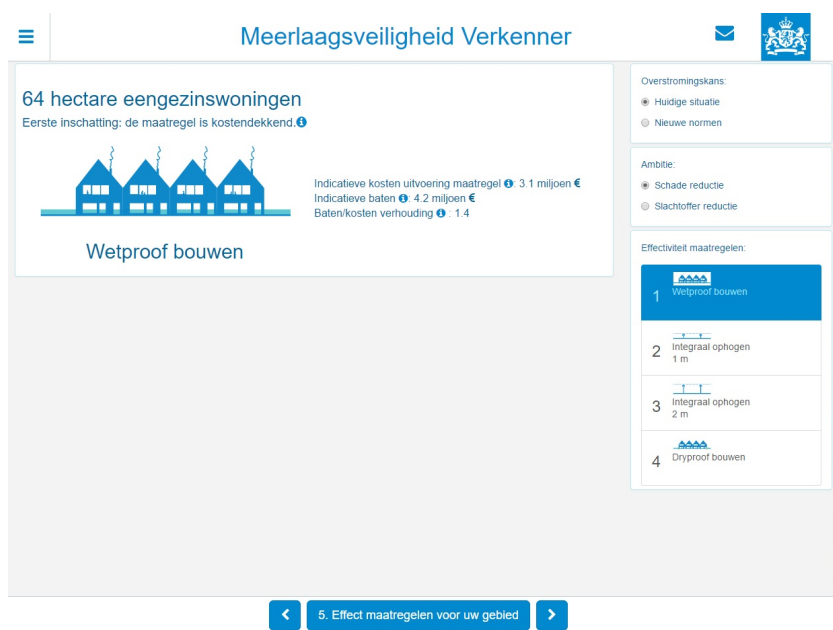


Figure C.23: This is an example of the wetproof building measure. You can see the results of this measure for the financial damage reduction, for the situation in which the new norms are have not been reached.

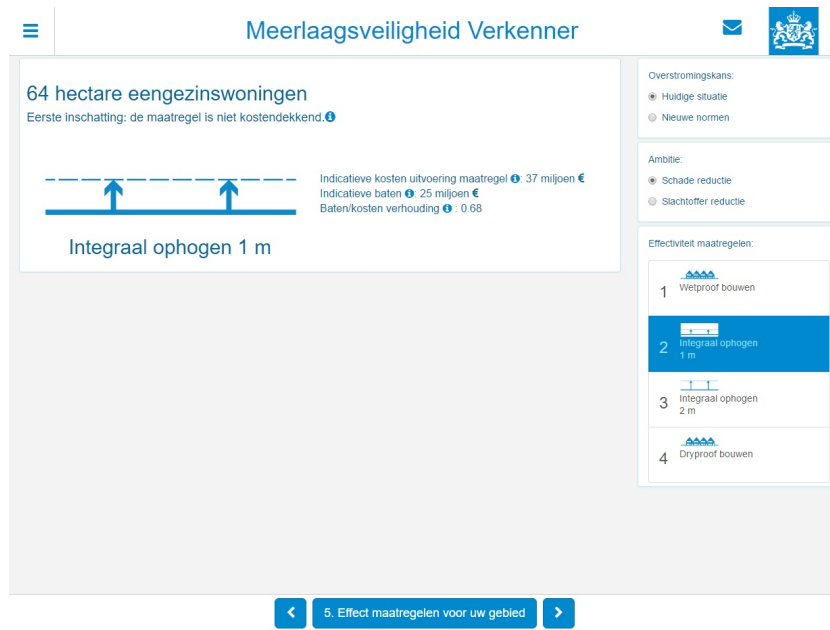


Figure C.24: Results for financial damage reduction of integral incrementing the subsoil with 1 meter, in the current situation.



Figure C.25: Results for financial damage reduction of integral incrementing the subsoil with 2 meter, in the current situation.

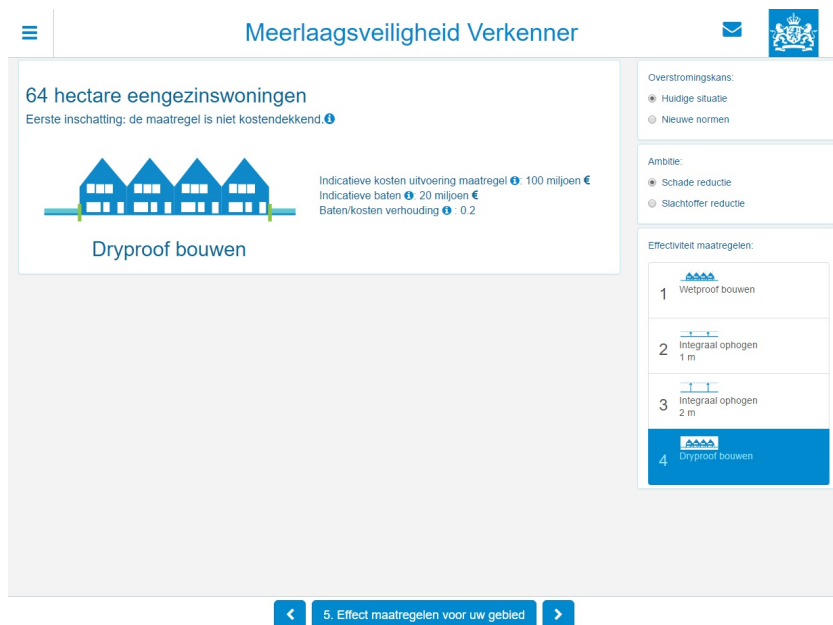


Figure C.26: Results for financial damage reduction after implementing the dryproof building measures, in current situation.

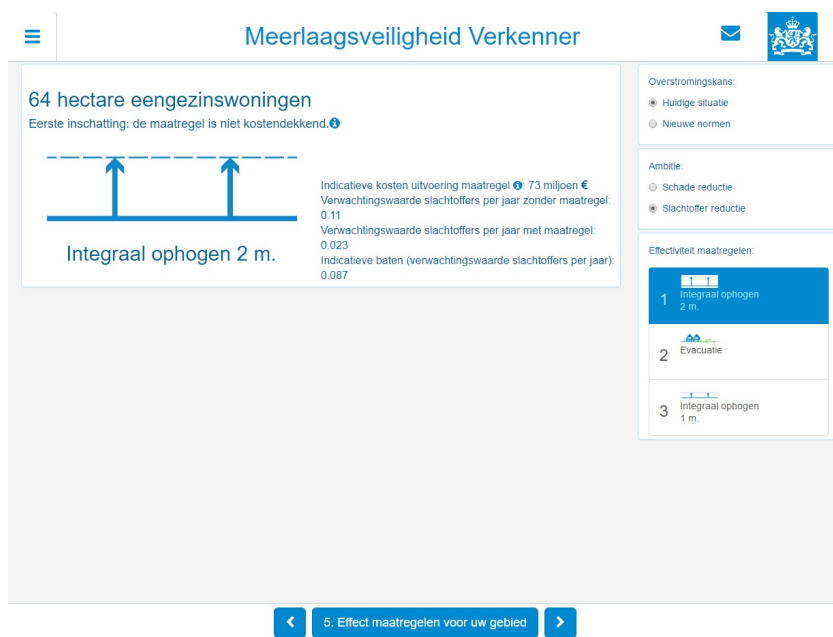


Figure C.27: Results for victim reduction after integral incrementing the subsoil with 2 meter, in current situation.



Figure C.28: Results for victim reduction after measures that make evacuation easier, in current situation.



Figure C.29: Results for victim reduction after integral incrementing the subsoil with 1 meter, in current situation.



Figure C.30: Results for victim reduction after wetproof building, in current situation.

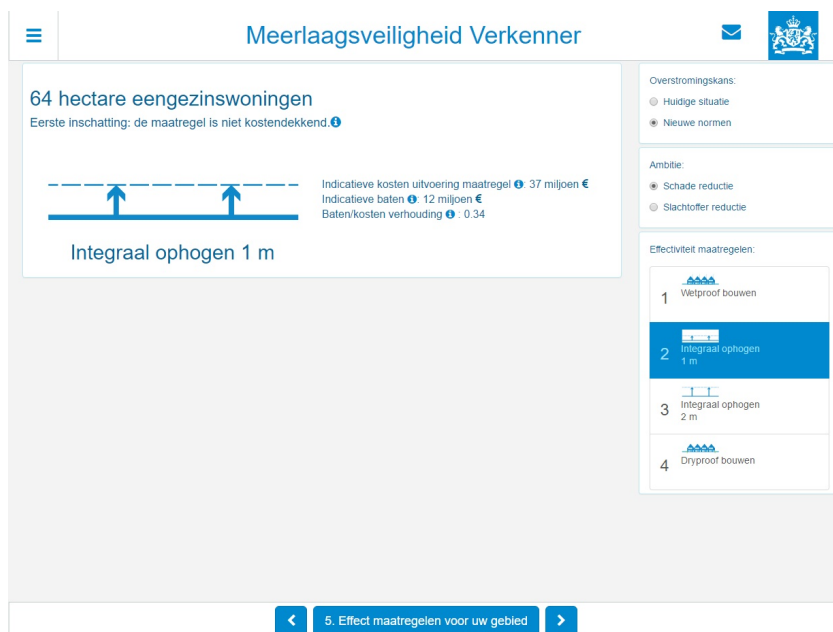


Figure C.31: Results for financial damage reduction after integral incrementing the subsoil with 1 meter, in case that the new norms have been established.

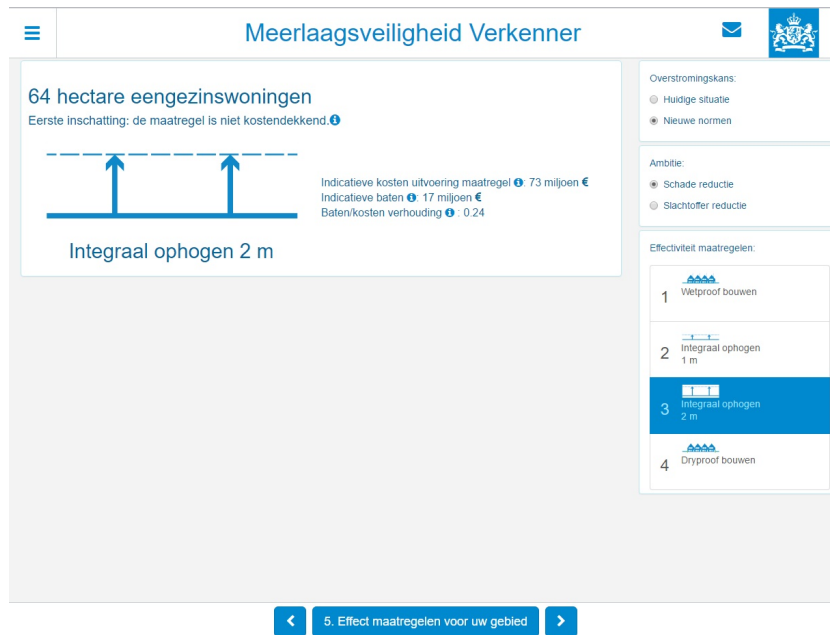


Figure C.32: Results for financial damage reduction after integral incrementing the subsoil with 2 meter, in case that the new norms have been established.



Figure C.33: Results for financial damage reduction after dryproof building measures, in case that the new norms have been established.

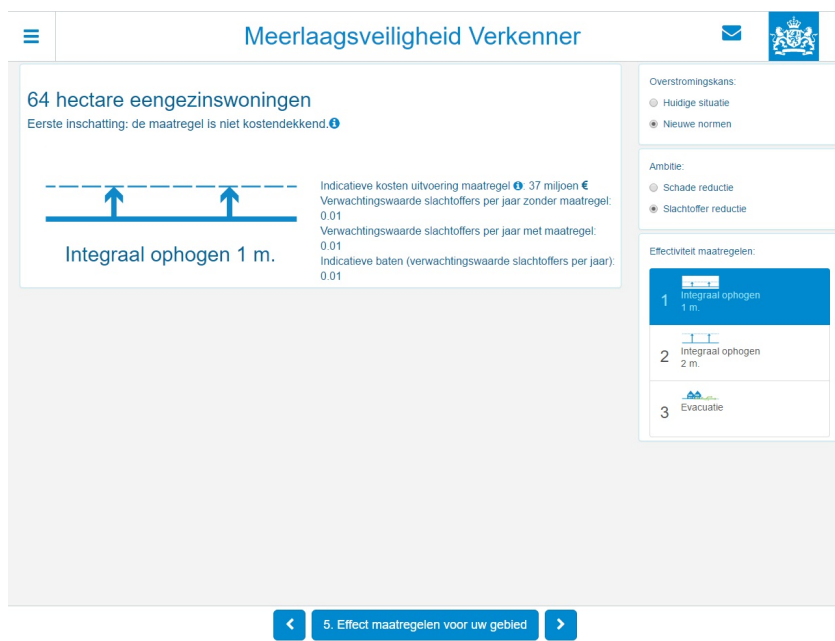


Figure C.34: Results for victim reduction after integral incrementing the subsoil with 1 meter, in case that the new norms have been established.

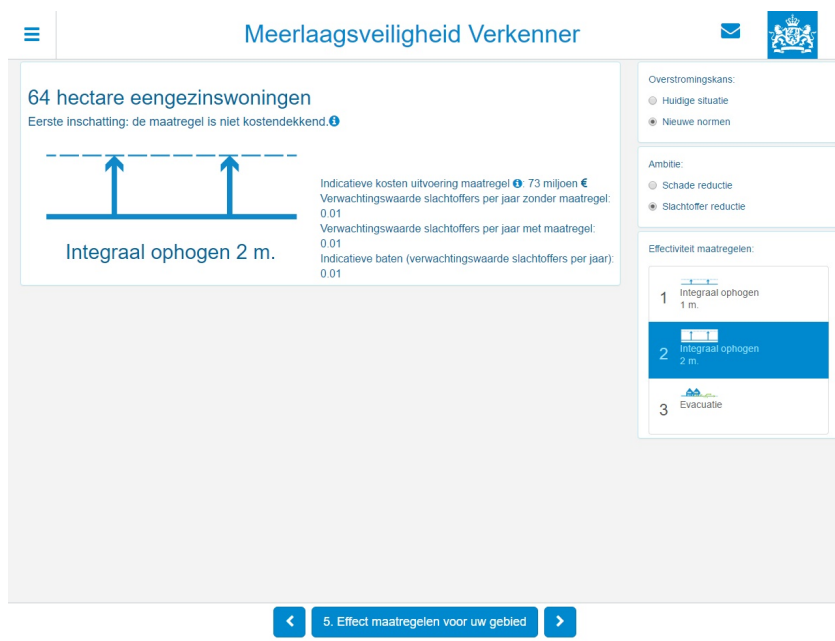


Figure C.35: Results for victim reduction after integral incrementing the subsoil with 2 meter, in case that the new norms have been established.



Figure C.36: Results for victim reduction after measures that make evacuation easier, in case that the new norms have been established.

STEP 6: ASSESSMENT FRAMEWORK

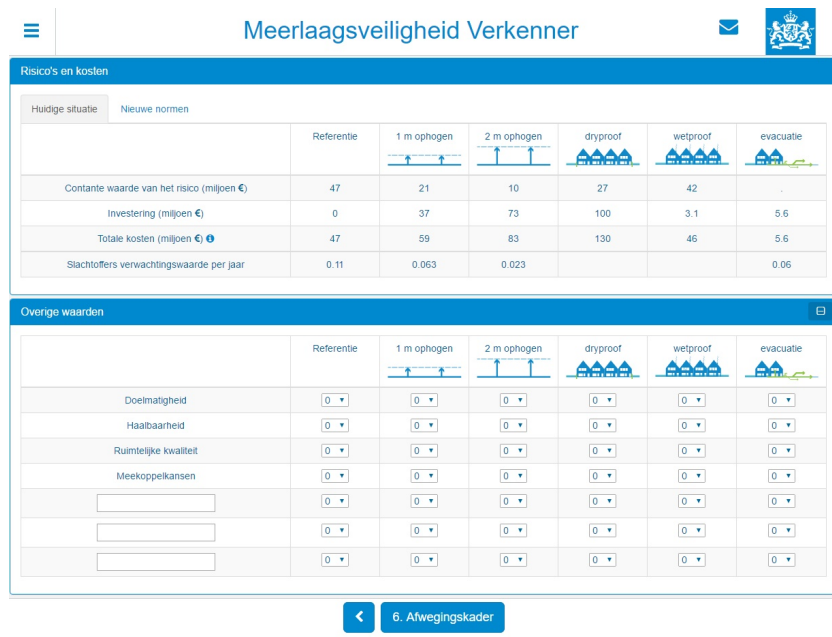


Figure C.37: Step 6 gives a total overview of all possible measures, it presents the present value of risk after implementing the measures, costs of the individual measures, the sum of these previous two and the expected number of victims in current situation and after implementing all separate measures. In such a table the indicative benefits and the benefit/cost ration should also be included

Meerlaagsveiligheid Verkenner

Risico's en kosten

Huidige situatie | **Nieuwe normen**

	Referentie	1 m ophogen	2 m ophogen	dryproof	wetproof	evacuatie
Contante waarde van het risico (miljoen €)	18	5.2	0.2	0.53	16	
Investing (miljoen €)	0	37	73	100	3.1	5.6
Totale kosten (miljoen €)	18	42	73	100	19	5.6
Slachtoffers verwachtingswaarde per jaar	0.0026	0.01	0.01			0.01

Overige waarden

	Referentie	1 m ophogen	2 m ophogen	dryproof	wetproof	evacuatie
Doelmatigheid	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾
Haalbaarheid	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾
Ruimtelijke kwaliteit	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾
Meekoppelkansen	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾
<input type="text"/>	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾
<input type="text"/>	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾
<input type="text"/>	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾	0 ▾

6. Afwegingskader

Figure C.38: The same table as figure C.37 but then for the situation in which the new norms have been established

COMPARABLE INSTRUMENTS

From the moment that the Delta-programme has called for new instruments that can help in coping with flood risk (Min. van I & M & Min. van EZ &I, 2011; Min. van I & M & Min. van EZ, L en I, 2011; Min. van I & M, 2013; Naeff, 2012), quite some instruments have been launched. Just experimenting with those instruments can already give good inspiration for improvement of the MLS-explorer. From the experimenting with these instruments, the main conclusions will be explained shortly.

Scanning through these instruments has functioned very well in gaining new ideas to improve the Explorer. Part of the analysis was just observation of the main differences and part was also personal preference, this user. The main distinguishing characteristics will shortly be summed up for all the instruments. The MLS-tool and the MLS-Explorer have already been explained in earlier in the thesis, they are included in the table in order to see the differences in comparison with the other instruments.

The **Climate-app** has two main distinguishing properties, first it lets the user select important characteristics of the foreseen location and project. And secondly it presents a long list with adaptation solutions, that is sorted from "most suitable" to "not interesting for this location or project type". The main advantage is that it helps thinking creatively about new solutions by presenting many ideas.

The **Climate effect atlas** is not very usable in small size locations, the main distinguishing properties are the possibility to switch between climate scenario's, give the possibility to analyse both flooding and precipitation, and the user can switch different map layers on and off in order to explore the differences and produce the image that is needed.

The **flood Risk profile website** offers the flexibility to experiment with different repetition times, or probabilities. This way the user can find its acceptable level of risk and preventive investments.

The **Delta portal** is a web-based geographical presentation tool that supplies information about the Delta model and Delta instruments. This information is stored in many different layers that can be selected from a menu. The main interesting part of this instrument is that it gives the possibility to explore four different climate scenarios and three different time perspectives, the user can easily switch between those seven options.

Compared to these instruments, the MLS-Tool has the advantage that it is flexible and very complete, almost everything the spatial planner wants to know can be calculated. Disadvantage is that it is difficult to use and only few experts can work with it. This disadvantage can be filled with the MLS-Explorer because it is very accessible. Compared to the other instruments the Explorer can give more specific information and is therefore more applicable for exploring small scale locations.

Some personal observations that can help gaining a better image of the differences between the instruments are given in overview table C.1. This is a short table of most instruments that are most comparable with the MLS Explorer. The analysis of these instruments resulted in inspiration for suggestions for improvement (see chapter 7.2)

Table C.1: An overview of other tools that are developed to inform about flood risk

Instrument	Weblink	Free or paid	Accessibility	Ease of use	Flexibility in calculations	Completeness/detail level
Climate app	online	free	high	high	low	medium
Climate effect atlas	online	free	medium	medium	low	medium
MijnOverstromingsRisicoProfiel	online	paid	low	medium	high	high
Delta portal	online	free	high	medium	low	low
MLS-Tool	Software	paid	low	low	high	high
MLS Explorer	online	free	high	medium	medium	medium

Some other interesting websites are [3DI](#), [deltaportaal](#), [floods.wri](#), [waterwindow](#) and [mappable](#) and many more are currently being developed or already online.

A general remark that can be made is that many of these instruments are not easy to work with, most spatial planners will probably need to read an instruction document or have a 1 hour training to learn to work with the instrument. Also sometimes the instrument seems to be not totally finished because there is information missing on a location where it is expected (co-benefits and details in climate app, locations of hospitals in climate effect atlas, and sub-programmes (of the Delta-programme) with no information in the Delta-portal).

D

CASE STUDY FRAMEWORK

This appendix goes deeper into the subject of chapter 4, where the case study framework was explained. A list of different location that were compared to possibly function as context for case study analysis can be found in figure D.2.

The whole design of the case study framework is based on the upper right form of four basic types of design that were explained by Yin (2013). In this research a case exists of one specific action which was taken in a spatial planning project. Now primarily the choice between single or multiple cases has led to multiple cases because this research aimed to find both differences and similarities between different spatial planning procedures. Secondly it was chosen to use the holistic variant over the embedded variant because of the earlier definition of a case, this was defined as the action. in this research the action was analysed totally from problem identification in the beginning up until the real action. This leads to the holistic case study design instead of the embedded which only picks several units of analysis from the case.

The Holistic multiple case design as shown in the upper right corner of figure D.1 is slightly changes into the variant in figure 2.1. In this figure the two context blocks stand for different locations, IJssel-Vecht and Maas-Venlo, and the cases stand for the four actions that were analysed.

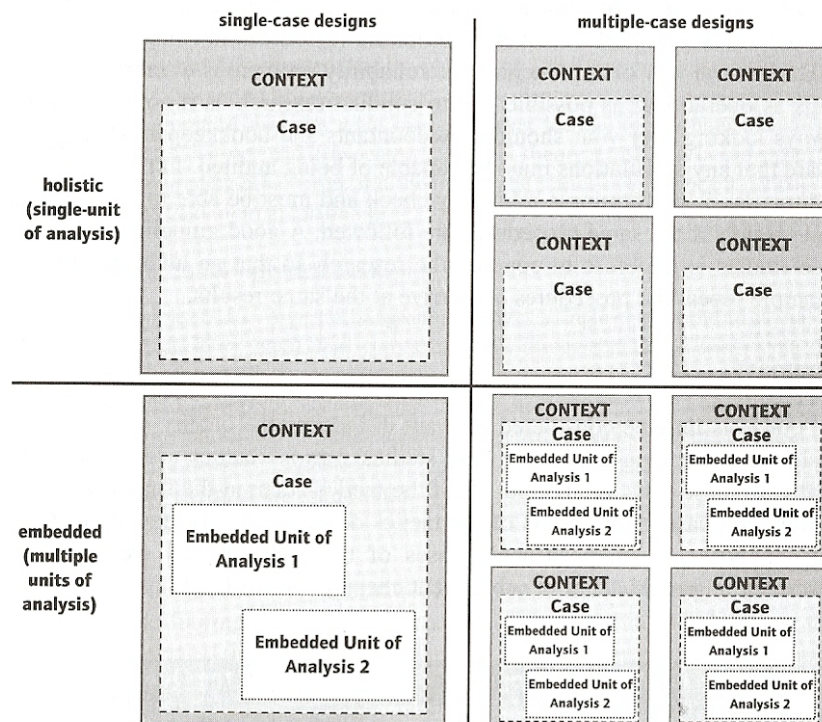


Figure D.1: The four basic types of design for case studies described by Yin (2013, p. 46). The research in this report used a variant of the upper right design.

Report	Report	Report	Booklet	Report	Website	Report of a meeting	
3 watergerelateerde MIRT onderzoeken	Evaluatie casussen reflectiebijeenkomst pilots MLV	Multilevel Governance voor meerlaagsveiligheid	MIRT inspiratieboek 15x Water en Ruimte	syntheserapport gebiedspilots Meerlaagsveiligheid Oranjewoud/HKV	www.meerlaagsveiligheid.nu	bijeenkomst ontwerpen water en ruimte	
Marken	Dijkkring 41	alblasserwaard	Hondsbosse en Pettemer Zeevering	Amsterdam	Alblasserwaard-	ijssel-vecht	
Dordrecht	Dijkkring 48	IJssel-Vechtdelta	Afsluitdijk	centraal holland	Vijfheerenlanden	venlo	
IJssel-Vecht delta	Brabant		Watergraafsmeer, amsterdam	dijkkring 36	Betuwe	dordrecht	
	IJsselvechtdelta (mastenbroek) inclusief kampereilanden		Marken	dijkkring 43	Borgharen Maasvallei		
	roermond		Rotterdam x2	dordrecht	Brabant		
	Limburgse eilanden		Katwijk	venlo maastricht	Centraal-Holland		
			Ooijen-Wanssum	schouwen-duivenland	Den Helder		
			Venlo	zuidelijk flevoland	Dordrecht		
			Waterdunen, Zeeuws vlaanderen		Eemsdelta		
			Oesterdam		IJssel-Vechtdelta		
			Tiel		kampereilanden		
			IJssel-Vechtdelta		Land-van-Maas-en-Waal		
			IJsselpoort		Marken		
			Lent		Rijn-Oost		
					Rijnmond Drechtsteden		
					Roermond en Horn		
					Walcheren en ZuidBeverland		
					Schouwne duivenland		
potential case ↓	mentioned in research? ↓	mentioned in research? ↓	mentioned in research? ↓	mentioned in research? ↓	mentioned in research? ↓	mentioned in research? ↓	score
ijssel-vecht	yes	yes	yes	no	yes	yes	6
Dordrecht	yes	no	no	yes	yes	yes	4
Venlo	no	no	yes	yes	no	yes	3
Marken	yes	no	no	no	yes	no	2
Roermond	no	yes	no	no	yes	no	2
amsterdam	no	no	yes	yes	yes	no	3
Rotterdam	no	no	yes	no	no	no	1
Tiel	no	no	yes	no	no	no	1
Lent	no	no	yes	no	no	no	1

Figure D.2: Scheme which was used to see which locations have sufficient documentation to do case study research

E

BACKGROUND INFORMATION FROM CASES

This chapter gives some more background information from the cases that were used in chapter 5 and chapter 6.

CASE 1

The planning process of this area exists of two different phases (Stadshagen I and Stadshagen II) (see figure E.1). For "Stadshagen I", the planning started in 1990 and the building in 1996. For "Stadshagen II", the planning initiative started in 2002 and the development around 2008. These two parts can be split up into different neighbourhoods. Stadshagen I exists of four parts, (Frankenhuis, Schoonhorst, Milligen and Werkeren) that are almost completely developed (see figure E.1). only Frankenhuis is still in development ([Ontwikkelingscombinatie Stadshagen, 2016](#)). Stadshagen II (De Tippe, Breecamp, and Breezicht) is in development, but the financial crisis that started in 2007 caused stagnation and currently only Breecamp is partly under development. De Tippe and Breezicht are set on hold in 2013 and for Stadsbroek it was decided that it will not be built, but it will function as leisure area ([Stadshagen Nieuws, 2013](#)).

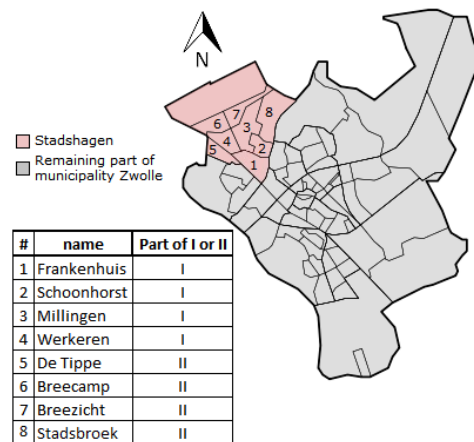


Figure E.1: Overview of different neighbourhoods in Stadshagen, part 1 started in 1996 and part 2 in 2008

CASE 2

This image gives an impression of the sound barrier that is realised around Stadshagen.



Figure E.2: Impression of the sound-barrier in February 2016. Locations that were finished in the top, the picture in the bottom left a tunnel that has to be closed in case of a flood, location where the sound barrier abruptly stops because neighbourhoods are not yet developed as can also be seen with the end of a road in the bottom right of the figure.

CASE 3

In the third case there are numbers explained that were coming from a Dutch report, written by authors from Infram, CSO and HydroLogic (2011). The following three figures show screen shots from tables that come from that report. This gives little more background to the numbers that were mentioned in chapter 6.4.

Situatie	Uitgangspunt	Potentiële schade (M€)					Initiële kosten (M€)	Coëfficiënt vermeden schade / realisatie
		Hele dijkkring	Gebied Tegelen en Maasveld	Gebied Venlo Zuid	Gebied Venlo Centrum	Gebied Venlo Noord en Velden		
Referentie	1	406	148	153	57	48	-	-
	2	301/288/250	105/92/76	125/125/103	35/35/35	36/36/36	-	-
"nul slachtoffers"	1	394	139	151	57	47	17,3	0,70
	2	36/288/250	0/92/76	0/125/103	0/35/35	36/36/36	-	-
"leven met de rivier"	1	453	205	153	47	48	74,1	-0,63
	2	183/161/71	147/0/0	0/125/0	0/0/35	36/36/36	-	-
"getemde rivier"	1	344	130	128	46	40	81,2	0,76
	2	29/29/29	0/0/0	0/0/0	0/0/0	29/29/29	-	-

Figure E.3: Potential damage from exploration for potential MLS measures (Infram, CSO and HydroLogic, 2011)

Situatie	Uitgangspunt	Potentieel aantal slachtoffers				
		Hele dijkkring	Gebied Tegelen en Maasveld	Gebied Venlo Zuid	Gebied Venlo Centrum	Gebied Venlo Noord en Velden
Referentie	1	5	1,5	2,5	0,5	0,5
	2	3/3/2	0,9/0,9/0,4	1,6/1,6/1,1	0,2/0,2/0,2	0,3/0,3/0,3
"nul slachtoffers"	1	0	0	0	0	0
	2	0/0,3/0,3	0/0/0	0/0/0	0/0/0	0/0,3/0,3
"leven met de rivier"	1	2	0,7	0,9	0,2	0,2
	2	0,5/0,8/0,4	0,4/0/0	0/0,5/0	0/0/0,1	0,1/0,3/0,3
"getemde rivier"	1	4	1,2	1,8	0,5	0,5
	2	0/0,3/0,3	0/0/0	0/0/0	0/0/0	0/0,3/0,3

Figure E.4: Potential victims from exploration for potential MLS measures (Infram, CSO and HydroLogic, 2011)

Thema	Aspect	Strategie		
		Nul-slachtoffers	Leven met de rivier	Getemde rivier
Veiligheid	Slachtoffers (en getroffen)	+	+	0
	Beïnvloeding waterveiligheid aangrenzende dijkringen (afwenteling)	0	0	-
Robuustheid	Extreme gebeurtenissen, klimaatverandering	+	+	-
	Ruimte voor natuurlijke processen	0	+	-
	Duurzaamheid van beheer	0	-	-
Haalbaarheid	Draaivlak	+	0	-
	Technische uitvoerbaarheid	+	+	-
	Realisatietermijn	0	+	-
Economische effecten	Kosten	+	0	0
	Vermeden schade	+	-	+
	Vitale objecten	n.v.t.	n.v.t.	n.v.t.
Omgeving	Effecten op gebruiksfuncties landbouw, natuur (EHS), cultuurhistorie	0	-	-
Ruimtelijke ordening	Functiewijziging	0	-	0
	Ruimtelijke kwaliteit	0	-	-
Beleidskader	RO-beleid	-	-	0
	Waterbeleid	-	-	0

Figure E.5: Score of the three strategies on all the chosen criteria. (Infram, CSO and HydroLogic, 2011) + = positive; 0 = neutral; - = negative

CASE 4

The Dutch government has set-up an official information profile that must be met in order to gain the formal MIRT status Figure E.6 is a screenshot of the Dutch information profile that is one of the requirements for receiving the status of start-decision during a MIRT process. Information profile for the Start-decision that was explained in case 4 (see Chapter 5.4).

INFORMATIEPROFIEL STARTBESLISSING

I. Opgaven / probleemanalyse

- Aanleiding, urgentie, onderbouwing en afbakening van de opgave (Inclusief Inpassing²⁰) met daarbij een omschrijving van het probleem en/of kansen, inclusief inschatting van de omvang en het schaalniveau en inclusief samenhang met rijksdoelen en regionale doelen, prioriteiten en belangen.
- Omschrijving (afbakening en kenmerken) van het gebied (stedelijk, landelijk) waarop de verkenning gericht is en eventuele gevoelheden (veiligheid, natuur, cultureel erfgoed etc).
- Omschrijving en afbakening van de thema's (infrastructuur, woningbouw, water etc.) en modaliteiten die in de analyse betrokken moeten worden.
- Omschrijving van het rijksbelang: legitimatie van de rol van de rijksoverheid, waarom (ook) het Rijk en niet (alleen) een lagere overheid.
- Omschrijving van samenhang tussen projecten en vastgoedbezit van het Rijk en projecten van de regio in het gebied en beoogde/ potentiële (synergie) effecten, in het bijzonder effecten op de sociale, economische en ruimtelijke ontwikkeling van het gebied.
- Omschrijving van de Rijks- en regionale verantwoordelijkheid voor de ruimtelijke kwaliteit en inpassing²¹.
- Omschrijving van de ontwikkeling van de opgave in de toekomst zonder ingreep; hoe ontwikkelt zich het probleem/de kans in de toekomst.
- Kansen, mogelijkheden en onderbouwing van de keuze voor een sectorale aanpak of integrale aanpak binnen de kaders van een gebiedsvisie en/of gebiedsagenda.

II. Oplossingsrichtingen

- Beschrijving van de reikwijdte van de oplossingsrichtingen.
- Beantwoording van de vraag of een structuurvisie wordt opgesteld, inclusief eigenaarschap (rijksstructuurvisie of provinciale structuurvisie), inclusief een verantwoording en motivering van de keuze. Wanneer het voorkeursalternatief meteen duidelijk is (verkorte Tracéwet procedure), is geen structuurvisie nodig.

III. Betrokken partijen

- Participatieaanpak op hoofdlijnen: welke partijen (maatschappelijke en private organisaties, burgers, medeoverheden) worden wanneer betrokken en waarover? Welke informatie is nodig van wie om tot besluitvorming te komen? Wie beslist waarover en wanneer?

IV. Financiën

- Voor projecten waar de scope – knelpunt en oplossing (inclusief inpassing) – bij de start duidelijk is en die in aanmerking komen voor de verkorte Tracéwet procedure wordt een life cycle budgetindicatie (inclusief beheer en onderhoud), inclusief onderverdeling van de bijdragen, van de betrokken partijen (co-financiering door Rijk, regio en/of markt) bij de startbeslissing opgenomen. Bij een rijksproject wordt aangegeven of er in de beoogde realisatiejaren voldoende budget beschikbaar is.
- Voor de overige opgaven wordt een globale budgettaire indicatie (indien van toepassing inclusief beheer en onderhoud en inpassing) met bandbreedte op gebiedsniveau en/of opgaveniveau aangegeven.
- Onderbouwing en voorstel met betrekking tot de verdeling van de benodigde middelen en personele capaciteit voor het uitvoeren van de verkenningfase.

V. Besluitvorming

- Is het voorstel al eerder of elders ingediend? Zo ja, wat was de uitkomst en waarom wordt het nu opnieuw ingediend?
- Bepalen van eigenaarschap/trekkerschap van de opgave/probleem en de verkenning (trekker is Rijk of regio), indien aan de orde met bestuurlijke duo's (regiocoördinator of rijkscoördinator).
- Voorstel voor de verdeling van rollen, taken en bevoegdheden in de verkenning.
- Beschrijving van de bestuurlijk-juridische procedure(s) die (mogelijk) gevolgd dient(en) te worden.

VI. Aanpak vervolg

- Beschrijving van de beoogde aanpak (inclusief motivering inzake instrument ruimtelijk ontwerp), doorlooptijd (in principe twee jaar) en planning (inclusief bestuurlijke beslismomenten) van de verkenning.
- Beoogde realisatetermin project.

Figure E.6: Dutch information profile for a start-decision (Min. van I&M, 2011).

ALL CASES

Table E.7 can be used to quickly recall the case studies. The main differences that hop out are that: The first case had no flood risk assessment. The second case, which was in the same area but two decennial later, definitely took into account flood risk and had a brainstorm session of two days where the MLS-explorer could have been usable. The third case was really in the beginning of a spatial planning process where there was not really a problem to identify. and the fourth case had lots of documentation since it followed an official national procedure. This case is also really in the beginning, where the MLS-explorer already could have been useful in a brainstorm session.

	Case 1	Case 2	Case 3	Case 4
Problem identification	large housing shortage	climate change + flexible water level in IJsselmeer + need to combine flood risk management with spatial planning	water safety policy has to be reconsidered, new approach is needed. Not really a problem, but a potential problem. As stated in by the last Delta Commission we want to prevent the next disaster from hapening	high water in the Meuse, led to high dikes, which people do not like. And mare space needed for expansion of logisitical capacity
analysis	study the tredn in housing demand	effects of climate change and flexible waterlevel	No problem analysis because it is fundamental research.	analysis towards promising prerspectives of koploperproject Maas-Venlo, resulted in five hotspots
set objectives	number of houses needed	find durable spatial design with concepts like MLS	find out which MLS measures have high potential	-Strengthening the primary defences and implementing the area specific sub-program "Rivers" from the Delta program - Doing research towards spatial and infrastructural tasks around Greenport Venlo - improve the water safety in Venlo and upstream areas -improve the urban structure with good opportunities for regional economic developments and spatial quality
design alternatives	Stadshagen, Herfte and IJsselfront	Official compartment dike, compartment shore	Zero victims, live with the river, tamed river	N.A. Or Waterstad, Balkon op de Maas en Maaspark
compare alternativs	scores 2.4, 1.7, and 1.5	exploratory research towards two alternatives, uring tacit knowledge	comparison upon different criteria	N.A. Or compared in a table with 41 measures
choose alternative	choise for location	choice between two variants of sound-barrier	combination of best scoring individual measures from all alternatives	N.A. Combination of the three alternatives
knowledge	information from EIS and more SP criteria, plus experience	expert judgement of needed space for both variants, experience with filling of missing sections	insight in combination of costs, benefits in long term, and potential damage	qualitative estimations
information	score upon criteria	information about estimated costs and effects on the risk inside and outside the neighbourhood for both alternatives	potential damage, potantial victims, innundcation depth, expeded time to predict a flood	waterlevel, critical infrastructure, costs of measures, number of dwellings, etc.

Figure E.7: Wrap-up of all individual phases from the four cases

In Table E.8 the whole list of information items that were distilled from the casestudies is given. In the different columns for every item it is given where it was found and if it can be useful to be presented by the MLS-explorer. This is explained in chapter 6.

Information item	function of the information	case specific	interesting for MLS explorer	used in case			Is this function achieved by the current explorer?
				2	3	4	
expected number of victims	estimate potential impact	no	yes	yes	yes	yes	yes
expected financial damage	estimate potential impact	no	yes	yes	yes	yes	yes
costs of different variants/measures	estimate costs of a measures	no	yes	yes	yes	yes	yes
potential water depth in case of a flood	estimate potential impact	no	yes	yes	yes	yes	yes
ground level of the location	can be used to see where it will be flooded/impact	no	yes	yes	no	no	yes
current infrastructural situation	Find critical areas/higher insight in location	no	yes	yes	no	yes	no
number of dwellings	estimate potential impact	no	yes	yes	no	yes	no
present dikes	gain higher insight in the location	no	yes	yes	no	no	no
effect of the waves caused by the wind	background information	yes	no	yes	no	no	no
location of corridors	these have to be filled in case of flood	yes	no	yes	no	no	no
minimal requirements of a dike	design level 1	no	no	yes	no	no	no
minimal requirements of a rampart	design rampart	yes	no	yes	no	no	no
vital objects in the area	Find critical areas/higher insight in location	no	yes	no	yes	no	no
maintenance costs of the measures	background information, can be included in costs of the measure	no	perhaps	no	yes	no	no
expected prediction time of a flood	estimate potential impact	partly	yes	no	yes	no	no
effects of a measure on nearby areas	gives secondary insight	no	perhaps	no	yes	no	no
robustness for extreme climate change	if-scenario	no	perhaps	no	yes	no	no
space for natural processes	has nothing to do with flood risk, but other stakeholders	no	no	no	yes	no	no
public support	contributes to chance of succeeding	no	no	no	yes	no	no
technical feasibility	determines if a measure is even possible in this location	no	yes	no	yes	no	no
expected term of realisation	gives better insight in the measure	no	perhaps	no	yes	no	no
expected financial damage in a future moment	sensitivity	no	yes	no	no	yes	no
expected evacuation fraction	influences the potential impact	no	yes	no	no	yes	no
mortality rate in case of a flood	influences the potential impact	no	perhaps	no	no	yes	no
costs to increase the protection level 10 times	sensitivity	no	no	no	no	yes	no
linking opportunities [meekoppelkansen]	give better insight	no	perhaps	no	no	yes	no
which area could flood in case of a dike-failure	can be used to see where it will be flooded, insight	no	yes	no	no	yes	no
expected hydraulic effect of a measure	get an idea of the water levels after the measure is implemented	no	no, too much detail	no	no	yes	no
surface	gain higher insight in the location	no	yes	no	no	no	yes
probability of flooding	estimate potential risk, impact	no	yes	no	no	no	yes
present value of expected damage	summarises different numbers in one information item, measure	no	yes	no	no	no	yes
Local individual risk (LIR)	summarises different numbers in one information item	no	no	no	no	no	yes
Local damage danger (LSG)	summarises different numbers in one information item	no	no	no	no	no	yes
benefits of a measures	gives better insight in the measure	no	yes	no	no	no	yes
benefit/cost ratio	gives better insight in the measure	no	yes	no	no	no	yes
Legenda							
insight							
impact							
measure							
sensitivity							

Figure E.8: Table with all information that was identified in the cases and what is presented by the explorer

F

SUGGESTED IMPROVEMENTS OF FOR THE MLS-EXPLORER

This appendix shows the possible screens that a user could see during the process that is explained for the suggested improved instrument, which spatial planners can use to assess flood risk. This description is given in chapter 7.2.

1. Draw area of development

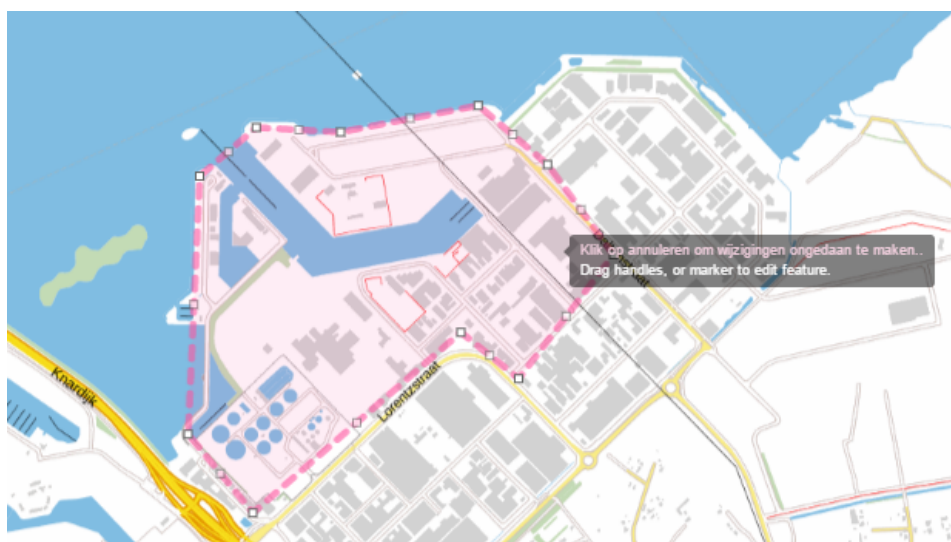


Figure F.1: step 1 of the new explorer, draw the foreseen area of development. This is a pure example, it is not the same location as other figures in this appendix

2. Decide if flood risk is significant

The system will calculate the flood risk and decide if this risk is significant, which means the remaining process of the Explorer should be performed. Or if the flood risk is not significant, which means the spatial plans can just continue without taking anticipation on the flood risks.

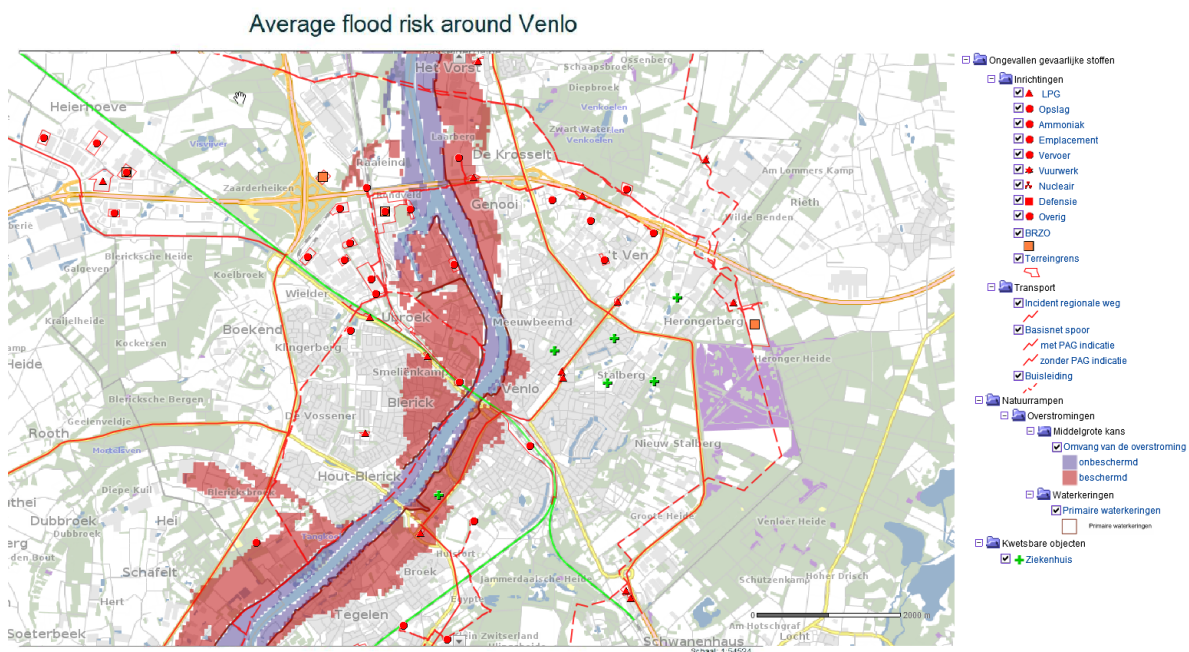


Figure E2: Map with potential flood and locations with critical infrastructure, from [risicokaart website](http://risicokaart.nl)

3. Select type of development

Now the user can select three different characteristics of the location (soil type, landscape characteristics like sloping of flat, and the type of flooding that they would like to take into account) and three characteristics of the desired development (percentage of different types of development like housing or industry, intensity on three different levels, and scale on four different levels.)



Figure E3: Select type of development and area characteristics

4. Calculate the risks

Now the system will just like the old system calculate the risk. But the information that is presented is more elaborated and gives the level of certainty of the calculations.

4. Show risks of the potential flood

Potential damage

Flood is expected to occur once every ... year	Expected water level	Expected damage	Expected victims
10	... M above NAP	... M €	... deadly victim
50			
100			
1.000			
10.000			
100.000			

Expected risk

In case of norm	Yearly estimated victims	Yearly estimated damage	Present value of damage
1/100	... victim/year	... M €/year	... M €
1/10.000			
1/100.000			

Ga verder

Figure F4: This table in the fourth step shows a list of values, that are interesting for the spatial planners, in different probability scenarios. This way the planners can choose their own level of risk that will be anticipated in the spatial plan.

In this same step the numbers that were shown in the table can also be presented in a map with different colours.

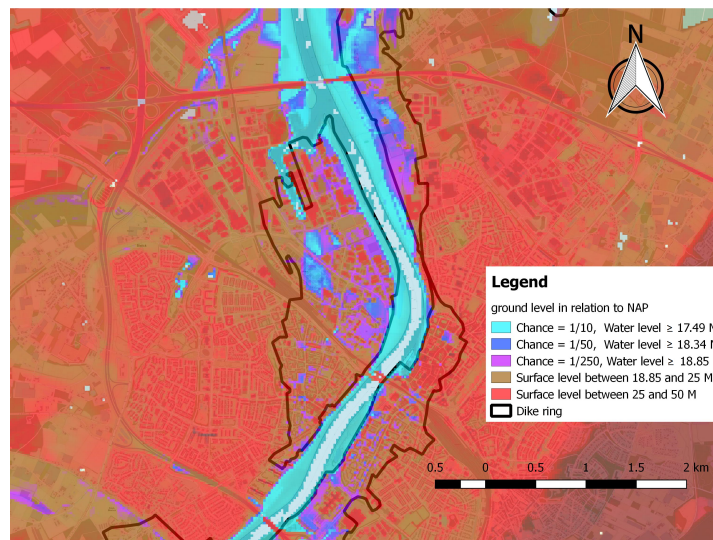


Figure F5: Example of an image that quickly shows the different locations that will be flooded in different scenarios, Made in QGIS for the location Venlo

Another item that can be shown by the instrument is the level of potency of a wide variety of measures for that specific location. This should be an inspiration.

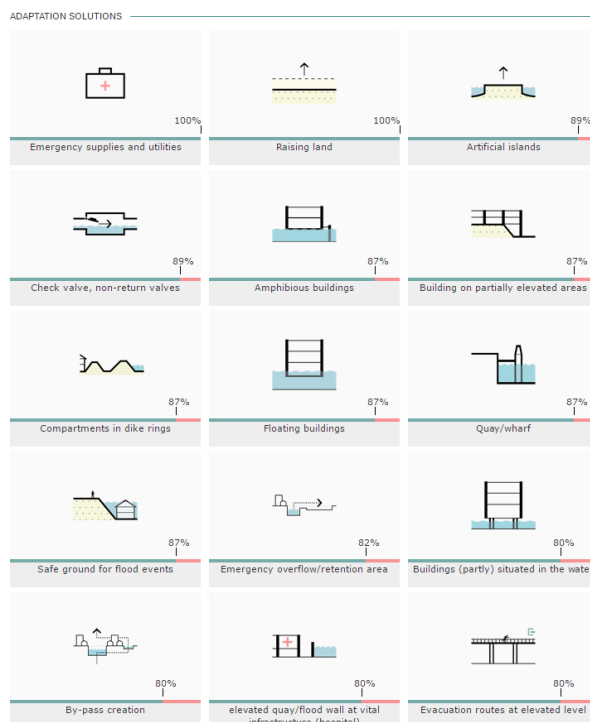


Figure E6: Overview of potential of different MLS measures that can be used in the new spatial development. (Image is taken from [climateapp website](#))

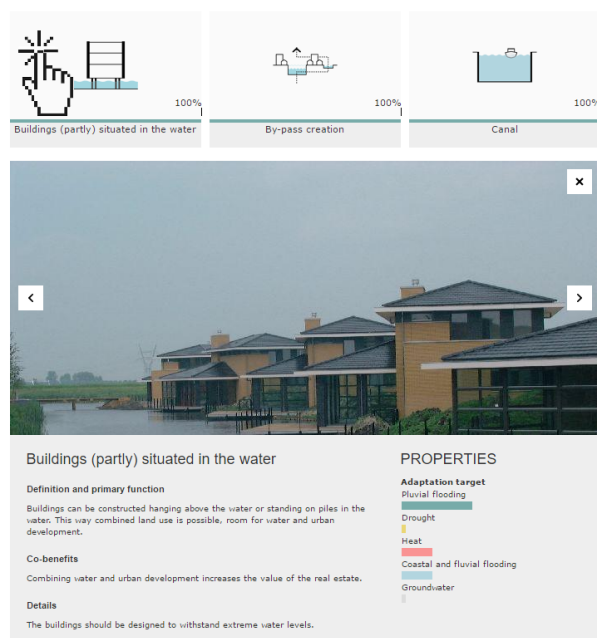


Figure E7: The user can click on a certain measure to see a brief explanation and properties like advantages and disadvantages. (Image is taken from [climateapp website](#))

5. Choose most interesting measures

Now in the fifth step, the user must get the opportunity to select the seemingly most interesting measures for a deeper analysis.

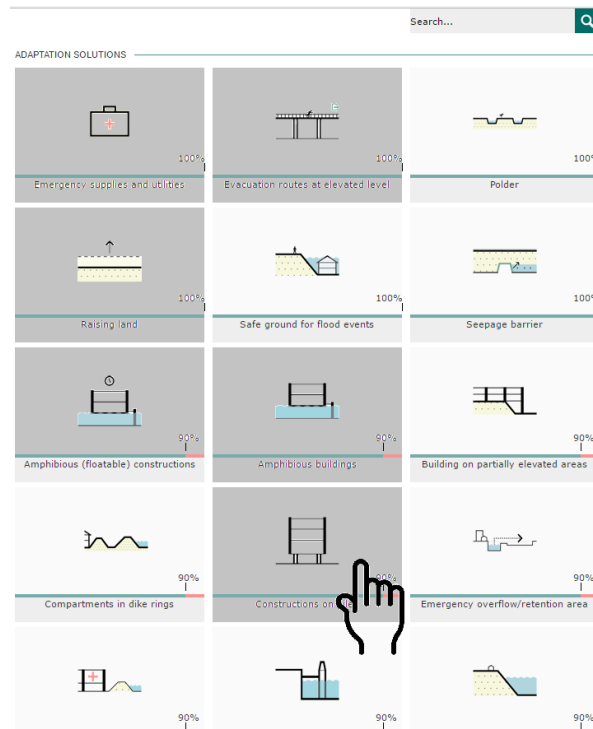


Figure E8: User selects most interesting measures

6. Determine effects of the measures

After the measures were selected, the instrument can calculate effects of the choices and present these effects in a visual and simple way that is quickly understood by a spatial planner.

6. Show effects of selected measures

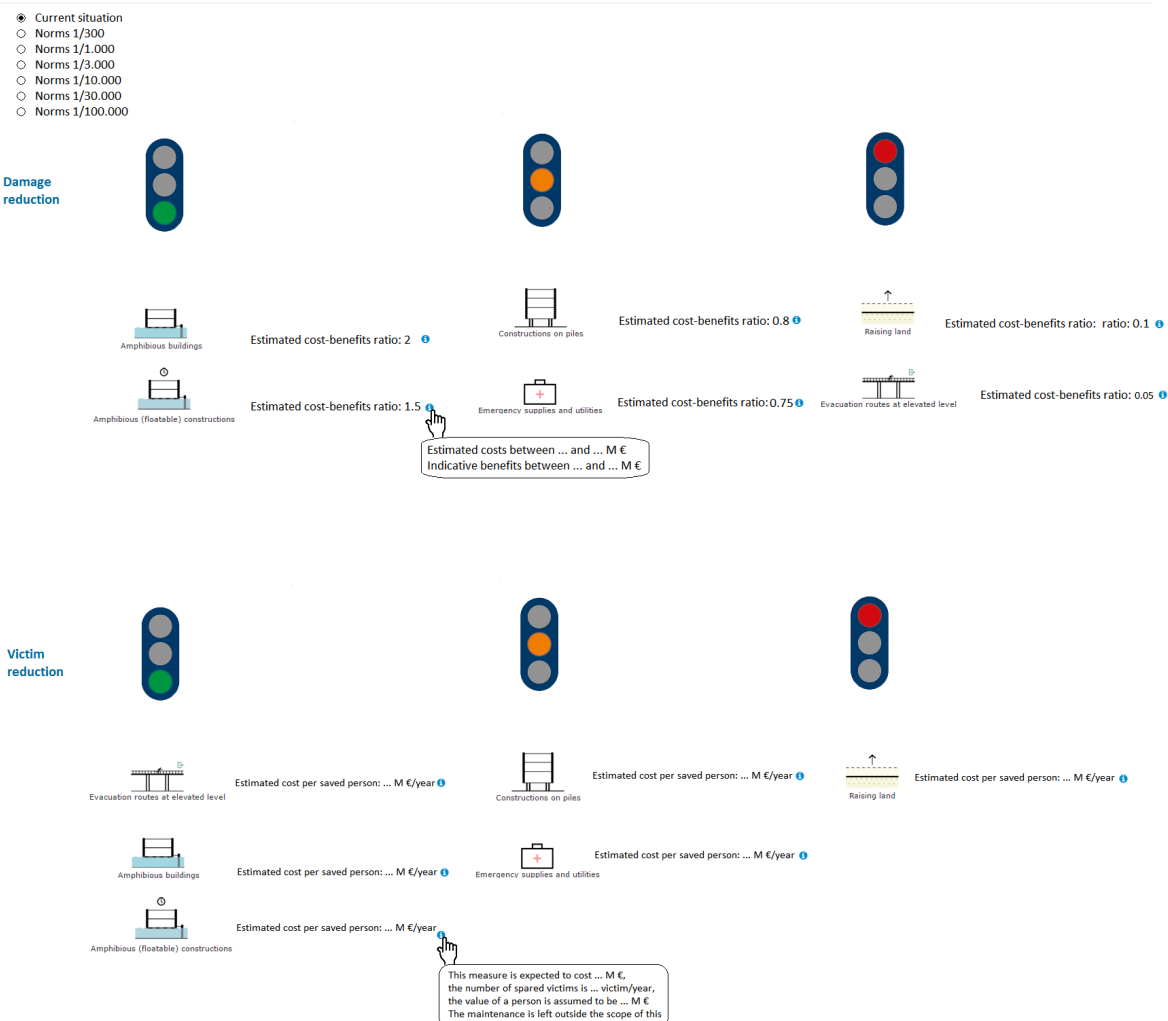


Figure E9: Now the previously selected measures are presented in different categories. Green light for highly potential, orange light for perhaps interesting, and red light for not very likely to be interesting

7. Change initial assumptions

In this seventh step, the user can turn the buttons, select, or fill in the values of several variables in order to find out how this effects the results.

7. Change initial assumptions

Select the areal properties and foreseen type of development

Discount rate initial assumed to be 5.5%

Economic growth

Climate scenario

Soil type

Sand
 Clay
 Peat
 Bed rock
 Do not know

Air circulation patterns

World temperature in 2050 compared to 1990

Used damage function

A B

Recalculate

Figure F.10: In the seventh step, several earlier assumptions can be adjusted in order to see what consequences this has for outcomes.

8. Recalculate the risks

Now after this last screen, the user can print the final report and send the drawn project to someone else. This report contains a web-link or id-number which the receiver can use in order to get the exact same project, and explorer this with different adjustment.

Input variable	Initial assumption	Changed in	Changed output variable	Old value	New value
Discount rate	5.5%	3.5%	Present value	5.2 M€	10 M€
""	""	""	Cost-benefit ratio	1.2	2.5
""	""	""
Soil type	Peat	Sand	Investment costs	37 M€	50 M€
""	""	""	Present value
""	""	""	Cost-benefit ratio

Figure F.11: In this last screen, the user can see the effects of the changes that were chosen in step 7. It will only show the numbers that have really changed due to this adjustment

G

RESEARCH PAPER

The importance of user analysis before the technical design of an instrument, which presents information to users from a different discipline

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14th of January 2018

Abstract

Flood risk is increasing due to climate change and the growth of the potential consequences of flooding. Analysing how flood-proof the spatial plan is, therefore becomes more important. Since most spatial planners have limited knowledge concerning flood risk, the Netherlands' Directorate-General for Public Works and Water Management commissioned the creation of an instrument that can be used by planners to gain a better insight into the flood risk. However, this instrument is used inadequately. This research paper explains the approach that was initially used to design the instrument and why this approach resulted in a product that is not adequately used by the foreseen users. This explanation is based on a model that delineates the process of transforming raw data into a desired result. With this model the potential for improvement can be outlined in a structured manner. It is concluded that during the design of the instrument, which was predicted to help specialists from a different discipline, it is important to first know who the foreseen user is, what information they need, and how this need can be covered in the design of the new instrument. In the end, the recommendation is to use an approach structured by the following sequence: (1) find out who has the responsibility for spatial planning that may be affected by flood risk, (2) analyse for what kind of result this user is generally aiming, (3) determine what action should be taken to achieve the result, and (4) what decision is needed in order to start the action, (5) find out what knowledge is required to be able to take the decision, (6) determine what knowledge the foreseen decision maker already possesses, and (7) what information is still missing in order to give the user sufficient knowledge, and (8) find out what data is needed in order to produce that information. After these eight steps of analysis, the following steps can be used to design the instrument. Then the final steps include (9) gathering the data, and (10) producing the information that can be presented to the spatial planners.

Keywords: DIKAR, Flood risk, Information, Knowledge, Multi-level safety, RAKID, Spatial planning

Number of words: 5.364

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1 Introduction

Despite the high level of attention given to flood risk, vulnerability is still increasing in the densely populated delta of the Netherlands. This is caused both due to the increasing probability of flooding as a result of the changing climate (which is partially addressed by classical measures), as well as due to the increase of potential consequences due to spatial development which lacked sufficient consideration of potential flooding. For a long time, the focus in the Netherlands was mainly on reducing the probability of flooding. However, a shift towards more attention being given to other aspects in the social and spatial environment resulted in a broader vision of how to reduce flood risk. This shift in focus resulted in more

attention being directed towards the reduction of the vulnerabilities and potential exposures that were identified from the 1970s onwards (Correljé & Broekmans, 2014). However, the implementation of this is still proceeding very gradually (Klijn et al., 2015).

In 2009, the concept of Multi-Level safety (MLS) was introduced into the National Waterplan by the Ministry of Transport, Public Works and Water Management (2009). This new concept advocates flood-risk reduction with measures that were placed on three different levels (e.g. reducing the probability of flooding, reducing the potential exposure, or reducing the vulnerability). An important difference in MLS is that the spatial planner needs to anticipate flood risk in an area, whereas this task was previously regarded as solely the task of the flood risk managers.

In 2014, an instrument named MLS Explorer was designed with the aim to assist spatial planners from multiple governmental levels with flood-proof planning (Bouwer et al., 2014). After the user has drawn an area and entered several characteristics of that area, this instrument presents flood-risk information for that specific area. The usefulness of having access to flood risk information during the spatial planning process is evidenced by an example from the Wieringermeerpolder in the province of North Holland. In this polder, Microsoft built a large data centre worth 2 billion euros (Edmonds, 2013). Such a data centre has numerous electric devices that are vulnerable to water. When a flood occurs (with an estimated probability of 1/700), the maximum water depth can reach 4.5 meters. Only one kilometre to the south, in West Friesland, the maximum water depth is calculated to be 1 meter, and also has a lower probability of flooding at 1/1000. This example raises the question of whether the higher risk is acceptable or if the current location is worth that much more than the other, less vulnerable, location one kilometre south? But it is possible that this information was unknown to the people responsible for choosing the location.

The example of the data centre is on a large scale. However, at a neighbourhood level, or even for private dwellings, it can be really valuable to explore the flood risk. Previous research has shown that it is difficult to design an instrument (e.g. the MLS Explorer) that helps users from a discipline different to that of the designers of the instrument (de Vries, 2017). The MLS Explorer was designed by flood risk specialists who have sufficient knowledge of flood risk in order to easily understand the output of the instrument. Despite the fact that the instrument was freely available on the internet, it was hardly used. This research paper will explain why the approach that was initially used to design the instrument did not achieve the desired result, and will suggest what could have been done differently. Therefore the central question is: How can one design an instrument that presents information to users from a different discipline, who need to make decisions based upon that information?

An important aspect to consider is that the designers come from a different discipline to that of the final user. Therefore their knowledge and terminology (jargon) may differ from each other. In chapter 3 of this paper some background information on flood risk and spatial planning will be provided. Subsequently, chapter 4 will explain the main point in this paper, namely that it is important to start the design with a result driven approach. Finally, chapter 5 will offer discussion and conclusions. However, before this, chapter 2 will explain the method that has been used to analyse the quality of the information that is presented by the existing MLS Explorer, and how this was used to recommend another way to design the Explorer.

2 Research Method

In order to analyse how the MLS Explorer was designed and more importantly, how it *should* be designed, a knowledge management model with the name DIKAR was used. The letters stand for Data, Information, Knowledge, Action and Result (Venkatraman, 1996; Ward & Peppard, 2002). The whole process, which is visualized in Figure 1, shows the transformation of raw data into information. This information can become knowledge if the person understands it. That knowledge can make a person more capable of making the best decision. This decision will lead to a certain action, which in turn produces a (desired) results. This whole process is called knowledge management. However, it can be divided into three smaller types of management. Firstly, ‘management of information’ concerns the transformation of data into the

right information. Secondly, there is the ‘management of competencies’. This is the management of both the level of knowledge in the head of the person who needs to take the action, as well as their level of power, commitment and experience. The third type of management is the ‘operational management’, which helps to ensure that the action does indeed produce the desired result. In between the five stages of data, information, knowledge, action, and result, four different gaps were identified. Firstly, the design gap is a problem with the consolidation of data and its transformation into information. This is often an ICT problem since someone needs to program what calculation consolidation should be performed with the raw data. Secondly, there is the expertise gap, which is often an organisational problem. Some people lack knowledge and/or expertise to interpret the information in the correct way. The third issue is called the leverage gap. This is again an organisational problem whereby those who possess sufficient knowledge, lack the empowerment to start the action. The fourth gap is a business problem in the form of an execution gap. This means that the action is performed, however, the intended result is not acquired. This can be due to mistakes made during the implementation phase that could have been prevented by better project management.

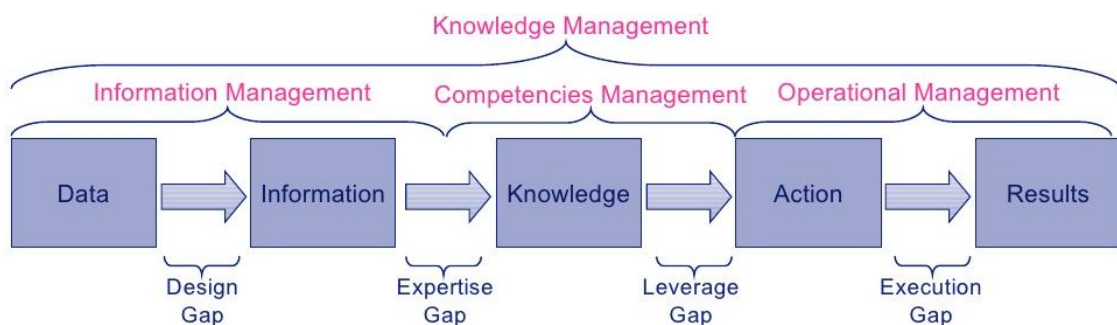


Figure 1: DIKAR stream with possible problems as a gap, and different types of management that can be used to solve the problems (de Vos, 2009).

The main focus in this paper will be on the design gap and expertise gap. In order to analyse how the design of the MLS Explorer could be improved, interviews were held with various persons from both the knowledge side of the expertise gap, spatial planners, as well as from the information side, the flood risk specialists.

An important distinction to highlight in this paper is the difference between information and knowledge. In order to do this comprehensively, the explanation of data should be added. Therefore, the first three steps of the DIKAR model will be explained, based on the articles of Hey (2004) and Murray (2000).

Data refers to unprocessed numbers and/or characters without any meaning. Data is a resource for producing information. Moreover, it is easily transferrable, discrete, and often available in abundance. An example is the numbers that a digital water level gauge sends to a computer.

Information is data that has acquired a meaning after it was processed. An example is the water level of the river. This is calculated by transforming the measured water level, in combination with the relative elevation of location where it was measured, into a water level in relation to the NAP¹. In general, multiple sources of data are needed to generate information. The information that is processed is generally easier to read for most users.

Knowledge is a ‘personal’ (and therefore, subjective) interpretation of information. It has a meaning for the information absorber who understands the information. Moreover, knowledge is not quantifiable, since it is located in the brain of an individual. Knowledge can be acquired by absorbing and seeking to understand different sources of information. An example of knowledge is that a person knows how high a river’s water level can rise before people need to be warned. Therefore, this person needs to know the current water level and the circumstances that will influence the situation in the coming hours. They also need to know the process that will be followed, mainly how long it takes, after it is decided that people

¹ NAP stands for the Dutch name Amsterdam Ordnance Datum [Normaal Amsterdams Peil]. This is a vertical reference height (geodetic datum) to which the height measurements are related.

need to be warned. In combination, all these aspects can render a person capable of making decisions about warning people or taking other actions aimed at reducing the possible impact of a flood. A brief overview of the main differences between the first three aspects is provided in Table 1.

Table 1 Main differences between data, information and knowledge

Data	Information	Knowledge
Is objective	Is objective	Is subjective
Has no meaning	Has a meaning	Has a meaning for a specific person
Is unprocessed	Is processed	Is processed and understood
Is quantifiable, there can be an data overload	Is quantifiable, there can be an information overload	Is not quantifiable, there is no knowledge overload

A downside of immediately starting with the DIKAR method is that the desired result is not yet known, which makes it difficult to design a way to transform data into the required information. In most cases the designers will have some kind of implicit result in mind, which is not yet explicit. This can be solved by first of all using the DIKAR method the other way around as RAKID. This result driven approach has already been explained by Murray (2000) and also later by Chaffey and White (2010). RAKID starts with a decent analysis of what the desired result is, who is responsible for taking the decision, and what this user needs to know before he/she can make the decision. This fourth chapter will explain what this means in terms of the design of an instrument like the MLS Explorer. However, before this some knowledge, which is needed to follow the reasoning in chapter 4, will be provided in the next chapter.

3 Necessary background on flood risk and spatial planning

Firstly a literal definition of flood risk will be explained in order to subsequently explain how this definition can be seen in Multi-Level Safety (3.1). Subsequently, a short explanation of the MLS-Explorer and the reason why it was developed will be given (3.2). At the end of this chapter the main differences between realms (or disciplines) of spatial planning and flood risk management will be explained (3.3).

3.1 Flood risk

The definition of flood risk that is used in this paper was adopted from article 2.2 of the European directive on the assessment and management of flood risks, which defines flood risk as ‘*the combination of the probability of a flood event and the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event*’ (European Parliament & European Council, 2007). This definition indicates that there are multiple aspects that influence the flood risk. Klijn et al. (2015) explained that a difficult aspect of dealing with flood risk is the fact that spatial planners and flood-risk specialists prefer different definitions of ‘risk’ (see Figure 2). The flood risk specialist is often an engineer who strives for flood risk reduction by means of flood protection in the form of keeping the water out. From this perspective, the flood risk can be calculated by multiplying the probability of flooding by the possible consequences, visualised in the first row of Figure 2.

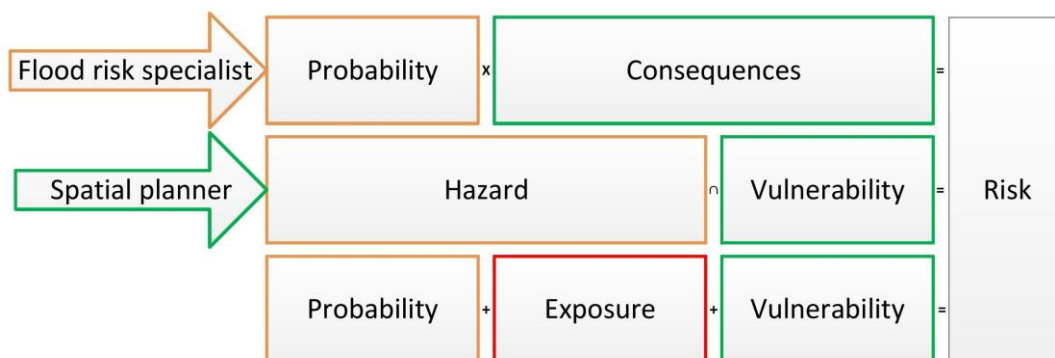


Figure 2: Overview of the differing perceptions of the definition of flood risk. Green is the responsibility of the spatial planner, orange is the responsibility of the flood risk specialist and red is the part that falls between both responsibilities.

From the perspective of the flood risk specialist, the flood risk specialist is responsible for minimising the probability of a flood occurring and the spatial planner is responsible for minimising the potential consequences.

The second perspective preferred by the spatial planner, is visualised in the second row of Figure 2. They divide the risk into hazard and vulnerability. Hazard is the responsibility of the flood risk specialist and vulnerability is the responsibility of the spatial planner. This definition is less easy to quantify since planners generally use social considerations to identify possible alternatives (and preferences are subjective), instead of hard calculations. In addition, the planners state that harm can only occur if there is both a hazard as well as vulnerability. Therefore, they use the intersection sign instead of the multiplication sign.

Klijn et al. (2015) suggested a new element called ‘exposure’ (red rectangle in the last row of Figure 2) as the element that falls in between the two earlier definitions. According to the spatial planner ‘exposure’ is part of the hazard, whilst the flood risk manager states that ‘exposure’ is a part of the consequences.

Elaborating on this flood risk definition, the reason for MLS and its meaning can be explained conveniently. Based on the need for more cooperation in order to reduce the flood risk with spatial planning, a new concept, with the name Multi-Level safety (MLS), was devised. In 2009, the Dutch government introduced this concept and, as the name suggests, it is comprised of different levels. The first level is prevention, and focuses on reducing the probability that a flood will occur (e.g. by building strong dikes or creating more room for the rivers). The second level aims at creating a durable spatial development that will help to minimise the potential (financial) damage when a flood occurs. With such a spatial development, both the potential exposure and vulnerability should be minimised (e.g. houses can be built on higher ground, or made flood-proof by using tiles instead of carpet on the ground floor). The third level focuses on the preparedness of people in order to reduce the number of casualties. Concrete examples include informing people about their risk and explaining how they can prepare for possible floods (e.g. how and where to flee, as well as training emergency services). This MLS appears adequate in theory, however, it was difficult to implement in the real world (van Buuren et al., 2013).

3.2 MLS Explorer

In order to stimulate the implementation of MLS-measures the Directorate General for Public Works and Water Management (DGPWWM, [RWS]) commissioned *Deltares*² and *HKV-Lijn in Water* to design an instrument that can provide spatial planners with the information they need to be able to take into consideration the flood risk and anticipate potential floods. According to the design-documentation, the foreseen users were policy officials representing municipalities, provinces, safety regions, water boards and the national government (Bouwer et al., 2014). Despite one single interview with a potential user the main approach undertaken by Deltares and HKV was thinking about the information they thought was important to present in this instrument, and also possible to produce with the available data. There are multiple sources of data (e.g. satellite data, water level measuring instruments, planes with laser scanners that fly over the country every two years to produce altitude maps, weather stations and water level measurement equipment, etc.) that can be used to produce information for flood risk assessment. The MLS Explorer provides information in relation to the following aspects (Bouwer et al., 2014):

- Type of flood risk
- Maximum water depth and probability of flooding
- Consequences of flooding in terms of damage and casualties
- Probability of the success of different kinds of measures
- Approximate indication of costs and benefits

² Deltares is an independent institute for applied research in the fields of water and subsurface

3.3 Realms of flood risk specialists and spatial planning

The reason that both disciplines use a different definition of flood risk stems from their roots. Both disciplines have a long history because of two characteristics of the Netherlands; it is a low-lying flood-prone country with a high population density. This makes it important to carefully organise the scarce space. There are differences between these two realms that have been traced in the literature. The Flood risk managers are more technically oriented and make ‘hard’ calculations that result in objective ‘best solutions’. However, spatial planners deal more with subjective opinions and therefore are more socially oriented, meaning that often, hard calculations are insufficient to decide which alternative is most desirable. An overview of several characteristics that describe the different realms is given in Table 2.

Table 2: Differences between the realms of flood risks managers and spatial planners, based on De Bruijn and Ten Heuvelhof (2010) and de Graaff et al. (2009)

Flood risk management	Spatial planning
Technical emphasis	Social emphasis
Technocratic decision	Democratic decisions
Only a few stakeholders play role	Many different stakeholders
Static	Dynamic
Project management	Process management
Best alternative can be objectively calculated	Choice for ‘best’ alternative is subjective

These differences lead to difficulties in the cooperation. For a long time these two realms operated quite independently from each other, but from the 1970s onward there has been a slow move towards a higher desire for cooperation (Correljé & Broekhans, 2014; Wiering & Immink, 2006). Spatial adaptation receives more attention in the Delta programme of 2016, which offers opportunities for new approaches in flood risk reduction.

4 Why it is important to start with RAKID instead of DIKAR.

Now with the information from the previous section in mind it will be explained why the design process, framed as DIKAR, should be preceded with a RAKID analysis in order to design an instrument like the MLS Explorer. The process can be explained with use of Figure 3, which shows the DIKAR process in a left to right funnel shaped process.

The process starts with lots of data (blue rectangles) that is gathered by the flood risk specialist in order to transform it into information (green rectangles). Several sources of information are used to form knowledge in the brain of the spatial planner. This knowledge (purple rectangle) is a combination of previously acquired information (e.g. the specific characteristics of the location), experience and skills (e.g. from earlier projects), and the flood-risk information that should be added in order to form the total package of knowledge. This total package is needed to make the decision about the best course of action (red rectangle) to reach the (desired) result. As demonstrated in Figure 3, the MLS Explorer (yellow rectangle) is at the boundary between the realm of the flood risk specialist and the spatial planner. More precisely, the part that is visualised on the computer screen forms part of the realm of the flood risk specialist, and the person who is reading it is part of the spatial planning realm. The focus is on this boundary between the flood risk specialist and the spatial planner, which is centralised around information. Therefore the next paragraph will explain how information quality can be assessed.

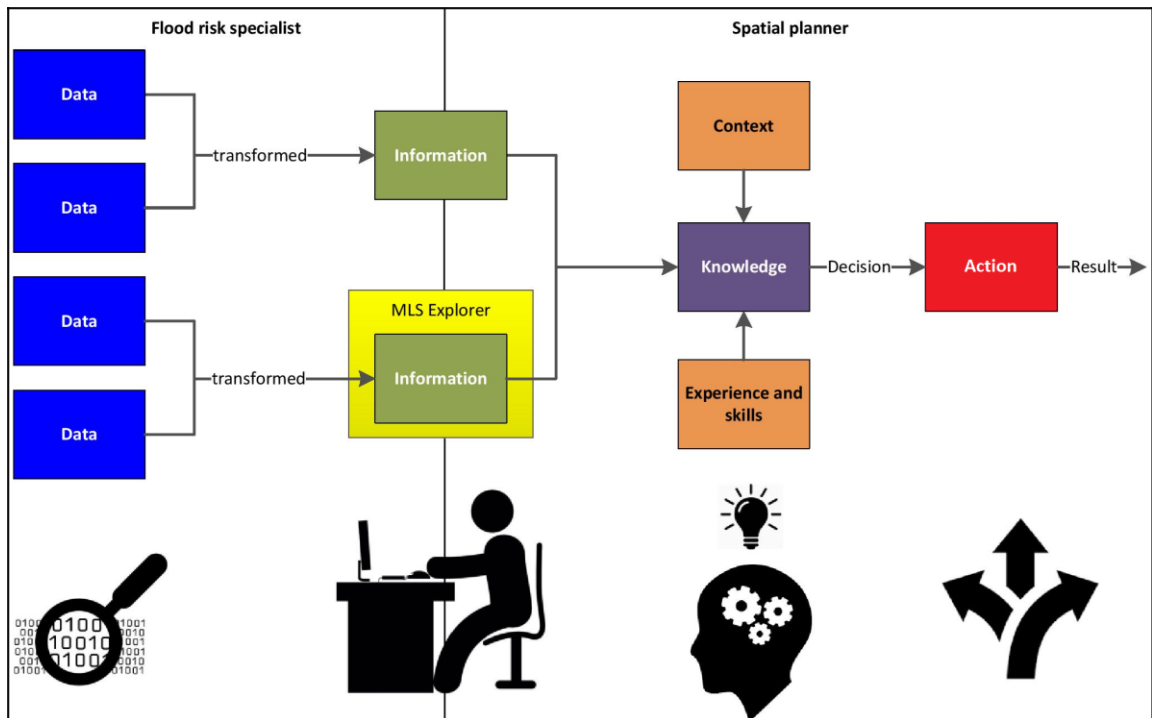


Figure 3 DIKAR process visualised with the MLS Explorer.

4.1 Assessing the quality of information

Quality of information can be assessed using different aspects. Information quality is described by English (1999) as the function of three input variables: (1) Data quality: if the data that is used as source for the information is incorrect then the information quality will be low since it is not based on reliable data. (2) Definition: the definition of the information item must be clear to the user so that he/she knows what it means. (3) Presentation: the presentation must be understandable to the user. Besides these three attributes, three more attributes concerning pragmatic information quality can be added: (4) Relevance, (5) availability and (6), timeliness. In this situation, timeliness (being up to date) is less important since the subject is about spatial planning, which often takes 5 to 10 years before it is realised and subsequently stays in place for a further 5 to 10 decades.

1. If we use the five remaining attributes (timeliness excluded) to assess the quality of information that is presented by the MLS Explorer, it can be stated that despite the fact that the majority of the data quality seems to be sufficient, the transformation of the data into information is not always correct. This was evidenced by the fact that some locations, which are located inside a dike-ring, were presented as an outer-dike area. This is because the algorithm behind the MLS Explorer uses map layers with a certain resolution that influences the outcome of whether a location is inside or outside a primary dike. If the user draws an area inside the dike, but close to the dike, and the area crosses one pixel that is partially located outside the dike, the instrument classifies the total area as outside of the dike. This could be solved by changing the resolution or adjust the coding in the algorithm.

2. The second attribute, that of information quality, means that definitions must be clear to the users, so that the meaning is consistently clear. This is not always the case in the MLS Explorer. During interviews it was discovered that two abbreviations, LIR³ and LSG⁴, were unfamiliar to almost all the spatial planners. Another example of difficult definitions is the probabilities that are presented to the spatial planners. An event that is expected to occur once every 100.000 years is difficult to comprehend for a person who does not regularly work with these types of probabilities. In this case it might be easier –and

³ LIR is the Dutch acronym for Local Individual Risk [Lokaal Individueel Risico]

⁴ LSG is the Dutch acronym for Local Damage Hazard [Lokaal Schade Gevaar]

more useful- for the spatial planner to explain the probability in another scale, e.g. the probability that flood will occur in the coming 50 years.

3. The next attribute, presentation, scores sufficiently in most of the visualisations within the MLS Explorer. However, sometimes there are maps with a legend that contains colours that hardly differ. In this presentation it is better to choose colours with sufficient variation so that the differences between areas can be quickly recognised by the user. Also, the overview of all possible measures that is given in the last screen of the MLS Explorer is not the best way of presenting the results. It is a large table with different type of numbers, which is difficult for many spatial planners to understand. The spatial planners that were interviewed explained that they needed more visualisations of the expected situation (de Vries, 2017). Therefore, a map that presents all the numbers, perhaps with the option to shift between different themes or different assumptions, could replace the table.

4. The relevance of information has two aspects. First, all information that is relevant should be presented and secondly, all information that is not relevant should be left out to prevent an information overload. In the current Explorer there is still information missing. This missing information is needed by the spatial planners to conduct an adequate flood risk assessment (e.g. locations with vital objects, borders of dike-rings and possible deviations in the calculations).

5. The last attribute is availability. The MLS Explorer is sufficiently available since the spatial planner only needs a computer and internet access to be able to use the instrument.

With this analysis of the quality of information presented by the MLS Explorer it can be concluded that there is room for improvement. Now the question remains, *how* could it be improved? The next section will explain how the result driven approach, as articulated by Murray (2000) and Chaffey and White (2010), has potential to significantly improve the quality of the MLS Explorer.

4.2 Result driven approach

The design method that was initially used can be identified as DIKAR. This has resulted in an instrument that is barely used. The main problem that was identified in previous research is that the information is not sufficiently understood by the users (de Vries, 2017). If the users had been better questioned prior to the design of the instrument, a better instrument could have been designed. The total process that is recommended can be defined as RAKIDDI: Result → Action → Knowledge → Information → Data-1 → Data-2 → Information. The first part ‘RAKID’ is the analysis and the second part ‘DI’ is the design of the instrument (as visualised in Figure 4).

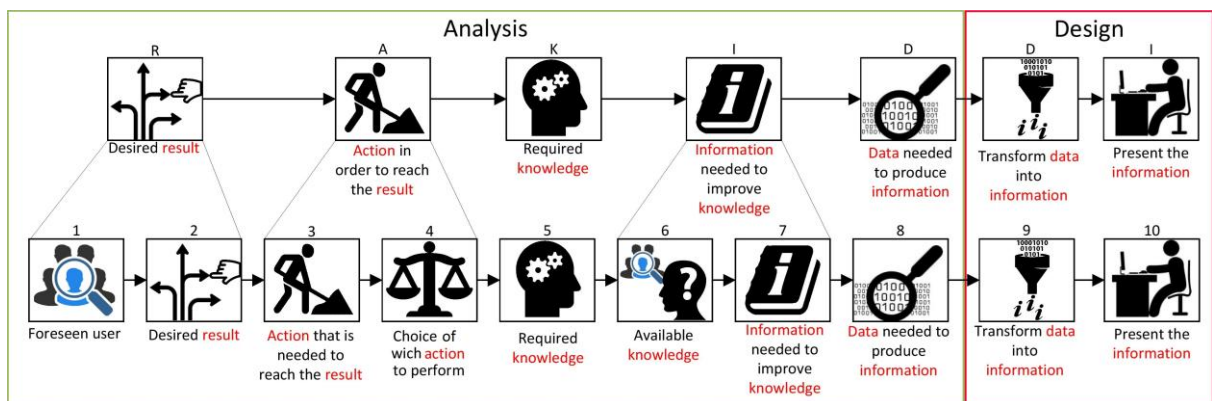


Figure 4: Schematic overview of the suggested approach to designing an instrument like the MLS Explorer. Visualised in the upper part with RAKIDDI that was retrieved from Murray (2000) and Chaffey and White (2010) and adjusted, as well as ten identified steps in the lower part.

If we examine the individual steps we can count a ten-step process. So instead of starting with the data and producing information for a wide group of users⁵, it is better to start with (1) a choice for the foreseen user of the instrument and (2), by analysing its desired result. Although this may seem obvious, it is an often encountered pitfall in designing a decision-supporting instrument. The chosen user must be specific since a more general group means a more significant variety in prior knowledge, which makes it difficult to design an instrument that can be easily used by all users. The next step is to (3) identify which actions the use of the instrument may assist, and (4) what decisions lead to these actions (e.g. a municipal official deciding to build a new neighbourhood at the south-western border of the existing city). If it is known what kind of decisions are relevant for this instrument, it can be (5) traced to what knowledge is required to be capable of making those decisions. Subsequently, it is important to (6) find out what the user, who was identified in step 1, already knows about this topic. If 5 and 6 are known, the lacuna between those two can be seen as (7) information that is needed to improve the knowledge of the user up to the required level. The last step of the analysis is to (8) distil what data is needed to produce the information. After the RAKID analysis of is performed, the DI-design can start with (9) gathering the data that was identified in step 8 and (10) transform this data into the required information. At this stage it is important to verify if the presented information is indeed understood by the user. If not, the designer should think of ways to improve the level of understanding as it means that the quality of the information is still insufficient. What is not understood must be analysed (step 6) and then steps 7 to 10. This process can be repeated several times until the information, and presentation of the information, has sufficient quality to bring the knowledge level of the user to the required competency to be able to make the decision.

5 Discussion and conclusions

Now the question, of whether it would be better to train the spatial planners so that they have sufficient understanding of the flood risk information, surfaces. In the visual in Figure 3, this can be explained as an investment in the upper green information square. Although this could be a solution to the problem, it is not an efficient solution. It would be expensive as the target group has to be identified and subsequently this group has to be trained, taking into account their previous knowledge.

The first difficulty is to identify the target group. Who should be trained? Is the training only for coastal and fluvial river flooding, or also for pluvial flooding? This then raises the questions of how often civil servants need this specific knowledge? Furthermore, how expensive is it to keep them educated at the desired level? This has high potential to result in inefficient training. In my opinion it would be less expensive, take less time, and therefore be more efficient, to train a smaller group of flood risk specialists in dealing with spatial plans. These specialists can be deployed throughout the whole country and assist spatial planners who have already explored the flood risk in their area.

A second downside of training the spatial planners is that this training has to be designed for all the spatial planners, or at least the ones that have been selected for deployment in places where there is a flood risk. The flood risk situation in the southern province of Limburg, which has upland areas and only deals with flooding from the river or precipitation, differs a lot from the flood risk situation in North Holland, which has low-lying land that is susceptible to flooding from the sea. This would thus make it difficult and expensive to have only one general training. This doesn't mean that the municipalities shouldn't do anything in relation to flood risk. If the spatial planners better understand what risk means and have access to an intelligible instrument that gives them sufficient and understandable information to explore the situation, I believe that these planners may slowly gain a better understanding of the flood risk aspects in their respective regions. This understanding can already be grown by using the improved MLS Explorer, but can also be improved by giving more general 'risk training' throughout the whole county.

The main conclusions can be summarised by the advice to start the design process of an instrument like the MLS Explorer with the analysis of the end user. This can be done by using the result drive RAKID model, and subsequently using the technology driven DIKAR approach, in order to produce a design that fits the

⁵ Important to note is that these are not the users of the final result but rather the users of the instrument. These users should base the result on the needs or desires of the people who live in the area.

demands of the end user. In this research paper the scope ran up until the information, which means the suggested design process can be expressed as RAKIDDI. An important point to mention is that this does not mean that the spatial planners do not need any training, but rather that the focus must first be upon the design of the instrument.

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