The valuation of stormwater solutions by experts and citizens

A Multi-Criteria Decision Analysis Framework for ranking stormwater solutions: the case of Oslo

Flood Kværnerbyen, Oslo, August 2015

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Master Thesis Water Systems and Global Change Group in partial fulfillment of the degree of Master of Science in Climate Studies at Wageningen University & Research, the Netherlands

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Abstract
Climate projections show an increase in frequency and intensity of extreme precipitation events in northern Europe during all seasons. This can increase the risk of flooding particularly in cities, as these consist of large areas of impervious surface. Green and grey stormwater solutions have been developed to reduce this risk. The Master Thesis is part of the project New Water Ways (NWW) in Norway. The case study is in Oslo, since stormwater is addressed as one of the most important challenges the city has to face in the future. Involving local stakeholders is important when making adaptation plans. Therefore, this study examined how experts and citizens of Oslo value different stormwater solutions (e.g. green roofs, bioswales and rain gardens). For this, I developed a Multi-Criteria Decision Analysis Framework (MCDA). In total, 22 interviewees and 43 participants of a questionnaire scored the selected stormwater solutions on their effectiveness, efficiency, feasibility of implementation and their side effects. In general, green solutions are ranked higher on these criteria than grey solutions. Reopening streams and rivers are ranked as highest by both experts and interviewed citizens while trees are ranked as highest by the citizens of the questionnaire. Underground solutions such as pipe systems scored lowest. The results can be used for improving valuation before and after the implementation of stormwater solutions and can support decision-making on the implementation of stormwater solutions. For decision-makers it is recommended to investigate in good communication with all stakeholders about stormwater solutions. To increase the overall effectiveness of the stormwater solutions, it is important to examine the combination of solutions. Furthermore, I recommend stormwater solutions that are multifunctional, so also can be used for e.g. recreation or parking lots. This promotes the acceptance of local stakeholders for stormwater solutions.

Keywords: climate adaptation, stormwater solutions, Multi-Criteria Decision Analysis Framework, stakeholder engagement, Oslo

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Abbreviations

IPCC	Intergovernmental Panel on Climate Change
LIDS	Low Impact Design
MCDA	Multi-Criteria Decision Analysis
NWW	New Water Ways
RCPs	Representative Concentration Pathways
SuDs	Sustainable Drainage Systems
WFD	Water Framework Directive
WSUD	Water Sensitive Urban Design

Chapter 1 Introduction

1.1 Situation

Climate change brings new challenges for humanity (Doherty, Klima, and Hellmann, 2016). Due to climate change, rising temperatures in the atmosphere and ocean lead to changes in hydrological cycles. More frequent and severe extreme precipitation events and therefore increasing floods are predicted (Parry, Canziani, Palutikof, van der Linden, and Hanson, 2007; Ruth and Gasper, 2008; Zevenbergen et al., 2010). Due to the increasing risks and uncertainty of climate change attention for adaptation has increased over the past two decades (Doherty et al., 2016). Despite the steps taken to mitigate climate change, attention and challenges of climate adaptation will grow in the coming decades (European Commission, 2013). The term was used for the first time in the 1990s and it is defined by the Intergovernmental Panel on Climate Change (IPCC) as: “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC, 2007, p.6).

Even though climate change is a global problem, the impact is experienced at a local level and can impact urban systems (Kazak, Chruściński and Szewrański, 2018), which gives those areas the incentive to develop adaptation strategies (Carter et al., 2015). There are several reasons why adaptation is needed in urban areas. Firstly, the trend of urbanisation continues during the 21st century (Carter et al., 2015), currently 54% of the world population lives in urban areas (The World Bank, 2018). Secondly, flood risk increases due to certain aspects in the design of cities. For example, sealed surfaces such as parking lots increase when cities expand (Cettner, Ashley, Viklander, and Nilsson, 2013) and rainfall can infiltrate less in those surfaces (Carter et al., 2015; Wagner and Krauze, 2014). Thirdly, especially urban areas are vulnerable to the physical impacts of climate change such as floods and droughts (Carter et al., 2015; United Nations, 2014; Zevenbergen et al., 2010). This is caused by factors such as dependency on an interconnected infrastructure, a high population density and high concentrations of material and cultural resources (Carter et al., 2015). Another major reason to advocate for adaptation is that floods are extremely costly and damaging (McKenna and Naumann, 2017; Ruth and Gasper, 2009), and adaptation can help in creating less damage and costs caused by heavy rainfall events.

In order to deal with floods and stormwater, a good adaptation strategy is required (Carter et al., 2015). Stormwater is defined as precipitation as rainwater or melted snow (Lindh, 2013). Dealing with extreme weather events has always been a major challenge for water management (Pahl-Wostl, Möltgen, Sendzimir, and Kabat, 2005). In conventional urban water management, stormwater is handled by the sewer system (Wagner and Krauze, 2014). Stormwater is channelled through the sewer system and transported away as fast as possible either to a wastewater treatment plant, or via separate stormwater drains that could discharge to a nearby river system (Lindh, 2013). However, this way of handling stormwater often leads to more problems because the sewer system cannot drain the rainwater fast enough resulting in flooded streets (Wagner and Krauze, 2014). Therefore, water management in urban areas has become more apparent (Cettner et al., 2013). An urban water system has to deal with changes in climate, population, urbanisation and densification. Showing that a shift from conventional to a more sustainable water management approach is needed (Pahl-Wostl, 2007; Pahl-Wostl, 2008).

There are several aspects that are important when it comes to adaptation in urban areas. It is important to consider all the factors and stakeholders that define the capacity to adapt (de Bruin et al., 2009; Lai, Lundie, and Ashbolt, 2008). Therefore, involving local stakeholders as well as experts when making an adaptation plan helps in overcoming the mismatch between top-down and bottom-up approaches and in making optimal decisions about adaptation (de Bruin et al., 2009). Involving citizens throughout the whole process of urban water management gives the possibility to increase the benefits of stormwater solutions, to raise awareness about water problems and increase understanding of solutions that are needed to deal with such problems (New Water Ways, 2016). The adaptive capacity in cities can increase when information and resources are shared. This way dialogues between different stakeholders can foster changes (Carter et al., 2015). Furthermore, decision-making on a local level suits better since local actions are often required for adaptation (Doherty et al., 2016).

For this study I will involve citizens and experts in ranking stormwater solutions, which are solutions that can be implemented to help a city to deal with rainwater and to reduce flooding during heavy rainfall. The case study is in Oslo, since stormwater is addressed as one of the biggest challenges the city has to face in the future (Olso kommune, 2014).

1.2 Study area

On 26 June 2014, major flooding occurred in parts of the city of Oslo, caused by 44.5 mm rainfall in one hour and 77.8 mm in one day. The large amount of impervious surfaces, limited capacity of the sewer system and lack of vegetation make the city vulnerable to flooding (Oslo kommune, 2016). Average annual rainfall has increased in the region of Oslo with ca. 16.5% since the beginning of last century, this increase mostly occurred in spring and least in summer. Due to increasing temperatures, more rainfall is expected because more will fall as rain instead of snow (Andenæs, Kvande, Muthanna, and Lohne, 2018; Norwegian Ministry of Climate and Environment, 2013). The IPCC uses four Representative Concentration Pathways (RCPs) that show how the climate will change under different conditions, with RCP8.5 as most extreme scenario and RCP2.6 as least. Under the RCP8.5 scenario it is estimated that precipitation will increase by ca. 15% by the end of the century in the region of Oslo, and for RCP4.5 it will increase by ca. 8%. Furthermore, more intense and frequent heavy rainfall events are expected: under RCP8.5 the number of days with heavy rainfall will increase with 89% and for RCP4.5 with 49% by the end of the century. This will lead to more stormwater runoff in urban areas, which could lead to an increase of the frequency and severity of flooding. In Norway, highest intensity rainfalls will occur around the Oslofjord (Hanssen-Bauer et al., 2017). To what extent Oslo will be affected by climate change depends on how much the climate will change, the adaptive capacity and the willingness to adapt to future changes (Norwegian Ministry of Climate and Environment, 2013).

In Norway, the municipalities are responsible for stormwater management. The stormwater in Oslo is currently handled by the sewer system. However, when there is a heavy rainfall event, there is often too much stormwater entering the sewer system, resulting in a mix of sewage and stormwater directly discharge in the sea or river system. Since the water is not treated, this can be a risk for public health. The stormwater can also lead to flooding on the streets or in buildings. Excessive rainfall is already causing damage, considering climate change this will increase (Norwegian Ministry of Climate and Environment, 2013). Traditional stormwater solutions are no longer sufficient (Andenæs et al., 2018). Therefore, Oslo municipality developed a new action plan in 2016 in order to deal with stormwater problems and to create a more resilient water system. This plan includes a three-step strategy visible in Figure 1. The first step implies that after light rain the water should infiltrate; the second step implies the retention of moderate rain; and the third step leading the water safely away after heavy rainfall (Oslo kommune, 2016).

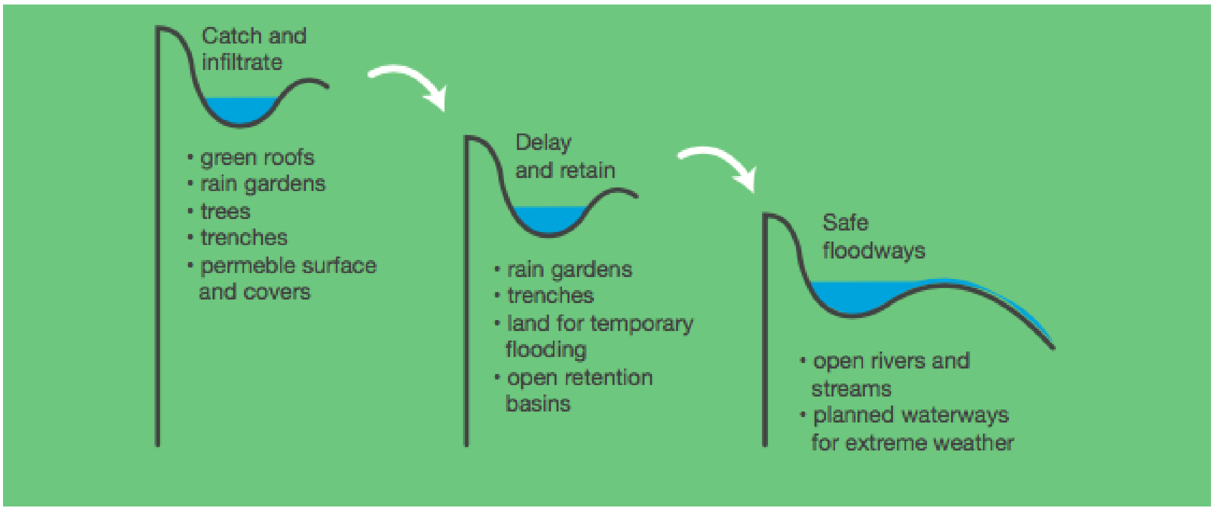

Figure 1. Three-step strategy stormwater solution in Oslo (Oslo kommune, 2016)

1.3 Problem statement

Even though sustainable stormwater infrastructure has many benefits and there has been worldwide focus for more than two decades, the implementation of such infrastructure is slow in urban areas (Dhakal and Chevalier, 2017). Uncertainty about the long-term maintenance and the performance of the solutions are limitations for a wider uptake (McKenna and Naumann, 2017). On the other hand, traditional infrastructure is still widely used (Brown and Farrelly, 2009; Dhakal and Chevalier, 2017). Also in Oslo, the challenge is to make the transition from conventional to sustainable water management and to increase the adaptive capacity of the city. For sustainable water management an "integrated, adaptive, coordinated an participatory approach" is required (Brown and Farrelly, 2009, p.839). Part of a participatory approach is to investigate the perception of urban residents and their interaction with sustainable stormwater solutions (Church, 2015). Therefore, letting experts and citizens valuate stormwater solutions can be used to define an appropriate set of stormwater solutions that are highly accepted among the stakeholders, which can support the implementation of sustainable stormwater infrastructure (European Commission, 2013). Furthermore, when understanding the perception of stakeholders it becomes clear what kind of problems can arise when implementing certain solutions and this can help planners, developers and decision-makers with how to best integrate sustainable stormwater solutions with multiple benefits (Apostolaki, 2006; Church, 2015). It also gives the opportunity to create more awareness amongst the stakeholders and helps to improve valuation before and after the implementation of stormwater solutions. The improvement of stormwater solutions can enhance public acceptability (Apostolaki, 2006).

1.4 Objectives and research questions

The aim of this Master Thesis is to understand the perception of experts and citizens in Oslo of several stormwater solutions. This is investigated by developing a Multi-Criteria Decision Analysis Framework (MCDA). This framework will help to answer the following question:

Which stormwater solutions are best valued by citizens and experts to prepare the city Oslo for increasing flood risk?

Sub-questions are:

1. Which stormwater solutions that are in general applicable in a Nordic climate should be used for the Multi-Criteria Decision Analysis Framework?
2. Which criteria should be used for the Multi-Criteria Decision Analysis Framework?

3. How are the different stormwater solutions valued by the citizens and experts?
4. What is the difference between the valuation of stormwater solutions by the experts and the citizens?

1.5 Relevance

This thesis is part of a larger project called New Water Ways (NWW). NWW steps away from conventional urban water management and wants to move to integrated water-sensitive and climate-adapted urban water management. Oslo municipality is one of the focus cities in the NWW project. The project is organised along six work packages. This study helps to interlink work package 2 (WP2) and work package 4 (WP4), namely: stormwater solutions evaluation and new ways of citizen participation (New Water Ways, 2016). WP2 evaluates urban water solutions that are relevant for Nordic cities, while WP4 focuses on ways "how citizen participation can contribute in the processes of designing, planning or implementing multifunctional stormwater infrastructure" (New Water Ways, 2016, p.9). The results of this thesis can be used as an input for both work packages and help in understanding the perception of citizens and experts of stormwater solutions. Furthermore, the results can also be used as input for decision-making on stormwater solutions. Making the change from conventional to sustainable water management is a challenging task. Using a decision matrix can be a good way to show the importance of more sustainable solutions to decision-makers and therefore support the decision-making process (Sieker, Peters, and Sommer, 2008). The Multi-Criteria Decision Analysis Framework will be applied in Oslo but is also applicable in other cities. This thesis therefore has a broader scope than just the NWW project.

1.6 Further outline of the report

Background information about used concepts and existing literature is given in Chapter 2. In Chapter 3 the methodology of this research is described. Chapter 4 presents the results, including the identification of stormwater solutions (4.1), ranking the stormwater solutions (4.2), stormwater challenges in Oslo (4.3) and a sensitivity analysis (4.4). The results are discussed in Chapter 5 and in Chapter 6 the final conclusion is given.

Chapter 2 Concepts

This chapter gives an overview of the concepts used in this thesis and existent literature on climate adaptation and urban stormwater management.

2.1 Climate adaptation

A side effect of increasing urbanisation rates is that cities become more vulnerable to flooding since a higher density of people is located in flood-prone areas (Zevenbergen, Veerbeek, Gersonius, and van Herk, 2008). Therefore, adaptation to climate change is promoted as an approach to reduce the urban system's vulnerability (Kazak et al., 2018) and to increase the adaptive capacity. Increasing the adaptive capacity of a city will help in handling floods better (Pahl-Wostl, 2007). The concept vulnerability is described in Box 1.

BOX 1: The concept vulnerability

IPCC defines **vulnerability** as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (Füssel and Klein, 2006, p.306).

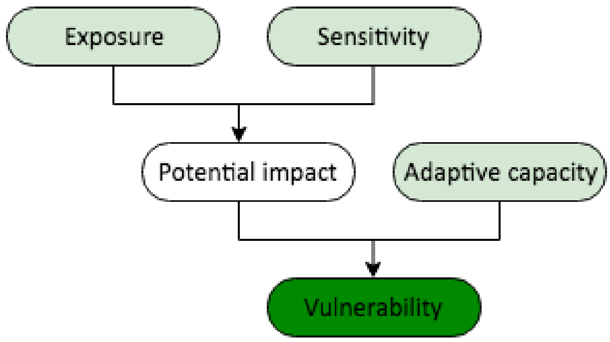

Figure 2. Components vulnerability (adapted from Gross, Woodley, 2016)

- **Exposure** is "*the nature and degree to which a system is exposed to significant climatic variations*",
- **Sensitivity** is *"the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli*", and
- **Adaptive capacity** is "*the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences*" (Füssel and Klein, 2006, p. 313, 314, 319).

This thesis focuses on improving the adaptive capacity of Oslo. The process of adaptation can be visualised in a cycle (see Figure 3).

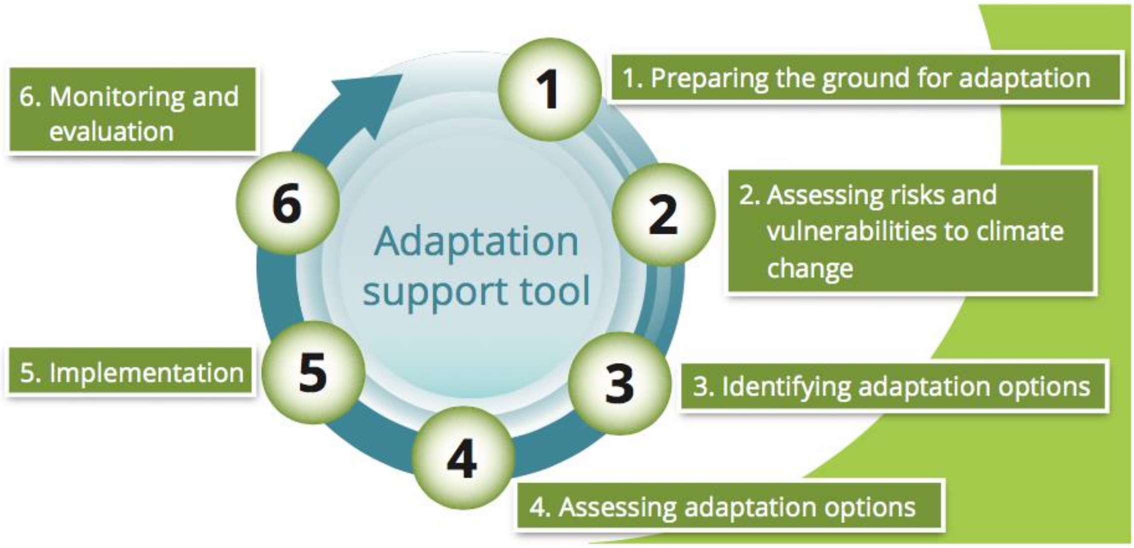

Figure 3. Adaptation support tool (European Environment Agency, 2015)

Where step 1 introduces the key elements needed for successful adaptation. Step 2 until step 6 are iterative, which means that those steps can be repeated. Step 2 looks in to the shortcomings regarding "knowledge on climate change impacts and adaptation" (European Commission, 2013, p.16). A vulnerability and climate change risks assessment can be done to address the main concerns. After the strategic direction is set, adaptation options can be identified in step 3. Those options aim to address those identified concerns. In step 4, the adaptation options are assessed and prioritised based on criteria. A multi-criteria analyses is a useful method for ranking adaptation options. This ranking can be used to develop a strategy document. This strategy can be used for step 5 to develop an action plan and move towards the implementation of the adaptation options. In most European countries, the implementation of adaptation options has just started. In the last step of the cycle the adaptation options are monitored and evaluated in order to get a better understanding which adaptation solutions are effective under specific conditions (European Commission, 2013).

The adaptation cycle is used as basis for this study. The NWW project has prepared the ground for adaptation and identified the vulnerabilities to climate change, namely flooding in Oslo. This study identified adaptation options in the form of stormwater solutions. Furthermore, it assessed the identified stormwater solutions. This sets the ground for implementing stormwater solutions and shows which factors are important for evaluating the implemented solutions. The following section explains why adaptation is needed in urban stormwater management and what is needed to make the urban system more resilient.

2.2 Urban stormwater management

Between the 17th and the beginning of the 20th century, stormwater management was seen as a completely technocratic and engineering process (Newman, Ashley, Cettner, and Viklander, 2013). For the development of urban areas, managing stormwater is often considered as a secondary issue. Stormwater management in developed countries, like Norway, traditionally makes use of drainage piped systems, which were introduced in the 19th century (Ashley et al., 2011; Åstebøl, Hvitved-Jacobsen, and Simonsen, 2004). The stormwater is disposed into the sewage system and then on to a water treatment plant. This system contributed to the welfare, safety and public health, since putting the water into an urban drainage system made waterborne disease outbreaks extremely rare (Ashley et al., 2011).

Until recently, this technocratic approach dealt with urban water challenges quite well (Ferguson, Frantzeskaki, and Brown, 2013). However, the expansion of cities, increase in sealed surfaces, and densification started to challenge this approach (Ashley et al., 2011). The uncertainties that come with climate change challenge this framework even further and the pipe system is currently not sufficient in dealing with stormwater management during heavy rainfall (Ashley et al., 2011; Pahl-Wostl et al., 2005), since those systems often result in flooding and pollution issues downstream (Ashley et al., 2011; Scholz, Uzomah, Almuktar, and Radet-Taligot, 2013). Furthermore, managing stormwater underground is a lost opportunity for a contribution to the liveability of the area, such as using green areas (Ashley et al., 2011). Therefore, a transition is needed from traditional to sustainable water management (Brown and Farrelly, 2009), that is more adaptive and holistic (Pahl-Wostl et al., 2005). Worldwide there has been increasing interest in a more integrated adaptive approach that increases the resilience of the system (Ashley et al., 2011; Cettner et al., 2013; Kazak et al., 2018). There is an emerging consensus that such an approach leads to more safe urban areas because the water is handled locally and involves more aspects than traditional systems; such as multifunctionality (Ashley et al., 2011).

Sustainable water management draws on natural processes to manage the stormwater, such as infiltration and filtration. The introduction of sustainability in urban water management has led to an increase in using local retention, source control and open drainage systems (Lindh, 2013), which are often called ‘blue-green solutions’ (Andenæs et al., 2018). This green infrastructure is described in literature with different terms, such as: ‘sustainable drainage systems’ (SuDS), ‘low impact design’ (LID) and ‘Water Sensitive Urban Design’ (WSUD) (Cettner, 2012; McKenna and Naumann, 2017). In this report they are called green solutions. Green infrastructure can be beneficial in terms of recreation, health, biodiversity, education on climate change adaptation, carbon uptake, air quality and water quality (Demuzere et al., 2014; McKenna and Naumann, 2017). The goal of those solutions is not to remove excessive water out of the city, but to retain it locally (Wagner and Krauze, 2014). The water disappears after a heavy rainfall event, mostly through evaporation and infiltration, and to a lesser degree through surface runoff and into sewer systems (Wagner and Krauze, 2014). Green solutions should prepare the city for extreme weather events and therefore increase the urban resilience (Kazak et al., 2018). Sustainable water management has therefore become more apparent in the past decades (Pahl-Wostl et al., 2005; Pahl-Wostl, 2007). Also, in Norway the interest in using such solutions in urban areas has increased (Åstebøl et al., 2004).

The increasing interest in transitioning urban water management resulted in a comparison of the technical framework with the sustainable framework (Newman et al., 2013; Pahl-Wostl, 2007). A short comparison of both approaches is given here. **Conventional water management** uses a ‘prediction-and-control’ approach and focuses on technical solutions (Ferguson et al., 2013; Pahl-Wostl, 2007) and bases decisions on cost-benefit analyses. The regime aims to control and secure, and assumes that rainfall patterns, the availability of resources and community values can be predicted (Ferguson et al., 2013). Furthermore, in this approach a centralised and hierarchical governance structure is used (Pahl-Wostl, 2007) with narrow stakeholder participation. **Sustainable water management** is more adaptive and flexible (Ferguson et al., 2013). This approach allows for broad stakeholder participation and uses a polycentric governance structure (Pahl-Wostl et al., 2005). Instead of controlling uncertainties, the approach aims at creating a more resilient system. This system takes into account that the risks cannot be reduced to zero (Ferguson et al., 2013; Gersonius, Zevenbergen, and van Herk, 2008). Due to the uncertainties of climate change there is not one best solution (Zevenbergen et al., 2008).

An effective adaptive management approach is robust under different scenarios, allows for changes, helps to create flexible institutional and technological systems and gives the possibilities for transparent learning and decision-making (Pahl-Wostl et al., 2005). There are many different solutions to handle stormwater, therefore the challenge arises to select the right solution (Sieker et al., 2008).

2.3 Participatory assessment

There are several aspects that are important when making the transition to an adaptive water management approach. Social, economic and ecological aspects should all be considered (Sieker et al., 2008). Over the last two decades there has been an emerging consensus on the importance of including a broad spectrum of stakeholders in decision-making (Munaretto, Siciliano, & Turvani, 2014). This is especially important for complex issues (Paneque Salgado, Corral Quintana, Guimarães Pereira, del Moral Ituarte, and Pedregal Mateos, 2009). A bottom-up management structure where **local stakeholders are engaged**, will increase the adaptability and therefore improve the flood resilience (Pahl-Wostl, 2007). For effective adaptation there should be broad participation of all layers of society (European Environment Agency, 2015; Pahl-Wostl, 2007). Local stakeholders could be involved in the decision-making processes and cooperate in the design, implementation and maintenance of the solutions (McKenna and Naumann, 2017). Another aspect that is needed when making the transition to more adaptive water management is **experimentation and social learning.** This implies that different actors, such as experts, authorities and the public should learn and become more aware of their environment and how complex the social interactions are (Pahl-Wostl, 2007). Water managers should integrate their view on how to deal with stormwater with the view from other professionals (Cettner, 2012). Furthermore, for successful sustainable stormwater management it is also important to consider **societal aspects**. Although the purpose of stormwater management is handling stormwater, an adaptive water management approach does not only deal with the reduction of flooding, but also has other environmental, social or economic benefits. When planning for stormwater solutions the natural conditions at the site and technical, economical and recreational aspects need to be considered. This makes planning in a city a very complex process (Lindh, 2013).

Several aspects should be considered when involving stakeholders. Every process of involving stakeholders differs, therefore stakeholders that bring different set of skills to the table are needed to improve involvement (European Commission, 2013). The process of stakeholder involvement is resource intensive; it requires for example human and financial resources (European Commission, 2013; van den Brink, Fidder, Remmers, and Schoonderbreek, 2018). Therefore, a clear process design is important to see how many resources are needed (European Commission, 2013). Furthermore, it is important that all stakeholders have similar expectations about the project at stake and that there is good communication and trust between the stakeholders. In order to get a high level of participation, it helps to points out issues that people can connect with, which can be done by making the project visible and fun (van den Brink et al., 2018). For this study, experts and citizens of Oslo are involved in assessing stormwater solutions.

Chapter 3 Methodology

In order to obtain the perception of citizens and experts of stormwater solutions, a Multi-Criteria Decision Analysis Framework is used. The assessment results in a ranking of the stormwater solutions.

3.1 Multi-Criteria Decision Analysis (MCDA)

Multi-Criteria Analysis is a commonly used method for analysing several adaptation options with different objectives (de Bruin et al., 2009), which has evolved since the 1970s (Garmendia and Gamboa, 2012). This method is a decision-making tool and uses the judgment of stakeholders to assess different options based on defined criteria, showing an overall order from the most preferred to the least preferred option (Dodgson, Spackman, Pearman, and Phillips, 2009; van Ierland, de Bruin, Dellink, and Ruijs, 2007). The approach allows for a qualitative and a quantitative assessment (Gough and Shackley, 2006; van Ierland et al., 2007). The method is furthermore suitable for understanding and including a broad range of perspectives, since it allows for stakeholder participation from experts and nonexperts (Gough and Shackley, 2006; Munaretto et al., 2014). A decision or performance matrix is used, where on each row the different solutions are shown and in each column the different criteria where the solutions are scored on (Dodgson et al., 2009). The results are aggregated in the matrix and can help with improving valuation and decision-making on stormwater solutions (Sieker et al., 2008).

Even though the final product of an MCDA is a ranking of the options, the main goal of scoring the stormwater solutions is not to reach a final best list of the solutions, but to gain valuable insights about the opinion of the involved stakeholders of the stormwater solutions and to see what issues can arise when deciding to implement certain solutions (de Bruin, Kelkar, and Mohan, 2014; Gamboa, 2006; Gough and Shackley, 2006; Salgado et al., 2009). There are several advantages of using an MCDA approach: the method is easy to understand; transparent; not dependent on the expertise of the participants (Gough and Shackley, 2006); open and explicit; the chosen objectives and criteria are open for changes; it allows for communication between decision-makers and the community (Dodgson et al., 2009); and it is possible to evaluate the solutions on more criteria (de Bruin et al., 2014). The method can be applied during a workshop, through interviews and/or by using a questionnaire (Gough and Shackley, 2006).

The following phases of applying a MCDA Framework can be identified:

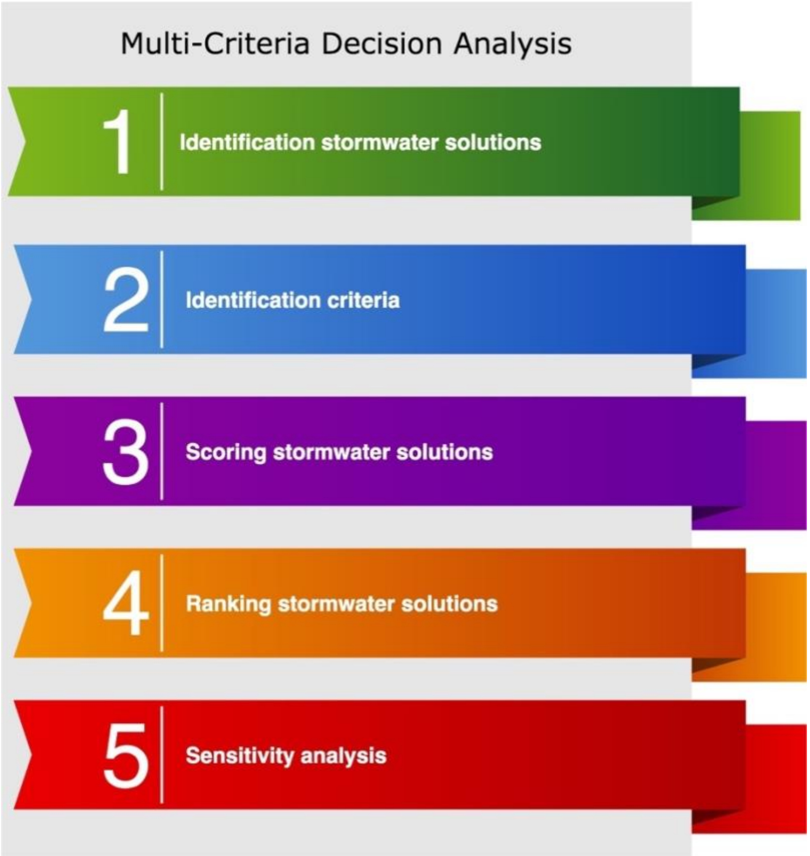

Figure 4. Phases MCDA Framework (adapted from Dodgson et al., 2009)

In phase 1 the options that will be considered in the MCDA Framework are identified, while in phase 2 this is done for the criteria. In phase 3, the identified options are scored on the identified criteria. In phase 4 weights for the criteria are selected to calculate the overall ranking of the options. In phase 5 a sensitivity analysis is done to calculate the overall ranking with using different weighting (Dodgson et al., 2009; Haque, Grafakos, and Huijsman, 2012). The following section applies this framework to this study.

3.2 Application of MCDA Framework

Phase 1: Identification of stormwater solutions

The different stormwater solutions are identified by literature study, including papers on solutions applicable in a Nordic climate (Andenæs et al., 2018; Jotte, Raspati, and Azrague, 2017; Koch et al., 2018; Martínez, 2016). A list of stormwater solutions has been created wherefrom a selection has been made. In total, a list of 13 stormwater solutions that can be used as input for the MCDA Framework is selected. This list includes green, traditional and socio-economic solutions.

Phase 2: Identification of criteria

Several criteria to rank the stormwater solutions are chosen via existing literature of Multi-Criteria Analyses. There exist several MCDA specifically for climate adaptation solutions, which are therefore used as basis for this analysis (European Communities, 2009; van Ierland et al., 2007; Weiland et al., 2015). In total, 16 papers have been analysed to create a list of criteria (Appendix I). This list was used and discussed with supervisors to select the criteria used in this study. The criteria are adapted to conditions in Oslo, which implies that some criteria are based on existing policies or plans of Oslo municipality that are of importance for stormwater solutions. In 3.3 the identified criteria are discussed.

Phase 3: Scoring stormwater solutions

During this phase, the different stormwater solutions were scored by experts and citizens. Scoring levels for the Multi-Criteria Decision Analysis from 1 (low) to 5 (high) have been used. With the selected stormwater solutions and criteria, the MCDA Framework has been designed. Two versions of the Multi-Criteria Analysis have been developed; one applicable for experts and one for citizens. In order to keep the model transparent it has to be simple (Gamboa, 2006). The Framework has therefore been discussed with several employees from NIVA and the supervisors of this thesis. Furthermore, the Framework has been presented during an internal meeting of the New Water Ways project to gain new input.

The results are collected, partly through interviews and partly via a questionnaire. For this study it was considered important to receive in-depth information from several participants, both experts and citizens, by interviewing them. A questionnaire was spread among citizens in Oslo to receive in total more input. The number of 43 participants does not give a statistical representation (Gough and Shackley, 2006).

Experts from different fields were selected in order to get a wide range of input, such as landscape architects, civil engineers and urban planners. The experts were selected through the network of NIVA and SoCentral and through the interviewees themselves by asking them if they knew more people in their network that were interesting to interview. The citizens were selected through different networks: by projects or contacts at NIVA (Sogn Hagekoloni) and SoCentral (Pådriv), through own social network and social media. It was important to aim that the involved people are representing the society of Oslo and that the conducted experts represent a wide range of expertise. Otherwise, the obtained data are of less value. This is because using information that does not represent the society, makes it more difficult to give a general conclusion on the perception of stormwater solutions. Therefore, this aspect has been taken into account when inviting people for interviews and spreading the questionnaire.

- Semi-structured interviews

The purpose of the interviews was to receive in-depth information about the opinion of experts and citizens of stormwater solutions that can be implemented in Oslo. This was done by scoring the different solutions on certain criteria concerning the effectiveness, feasibility of implementation, several side-effects and the efficiency. Two interview guidelines were designed: one applicable for experts and one for citizens (both in Appendix II). The guidelines look into all the criteria and include open questions in order to understand the reasoning behind their scoring of the stormwater solutions. Furthermore, the guidelines left space for follow-up questions. Several employees at NIVA were asked to give feedback on the formulation of the questions and the expert guideline was tested with one landscape architect, which resulted in some changes to make the questions more specific. Material used during the interviews were: pictures of the stormwater solutions, description of the scores, and the decision matrix to score the solutions. In order to engage the participants in scoring the stormwater solutions, they were given the possibility during the interviews to rank the criteria in order of their preference. Allowing the participants to prioritise the criteria can give insight in what is important to them when decisions on stormwater solutions are made (Garmendia and Gamboa, 2012). However, during the interviews it was not possible to adjust the selected stormwater solutions and criteria because then the results would not be comparable with each other. But in order to involve the interviewees in the process, they were asked to address additional criteria and stormwater solutions that are important for decision-making on stormwater solutions. This can give valuable input for decision-makers and for further research.

- Conducting interviews

Both experts and citizens were contacted by mail to invite them for an interview. In total 39 people were approached for interviews, wherefrom 22 interviews were conducted. In total, 8 citizens and 15 experts gave their opinions on several stormwater solutions (Appendix III). The interviews were conducted at their offices, at SoCentral or in a café. The interviews started with a brief explanation of this study and the interviewees were given the possibility to withdraw from the interview at any time. The interviews were conducted between 20 March 2019 and 3 May 2019 and lasted between 45 minutes and two hours. They were recorded and afterwards summarised for analysis. The summaries were sent to the interviewees in order to check if they agreed with the information that was collected.

- Online questionnaire

The purpose of the questionnaire was to collect more data from citizens (Appendix IV). Since interviews are time consuming, some people prefer to fill in a questionnaire that demands less of their time. Furthermore, using a questionnaire can complement the interviews and gives in total a wider range of input than the interviews alone. The information received from the questionnaire gives less in-depth information about the reasoning behind the scoring, but still provides information about the opinions on stormwater solutions. The questions were mainly based on the interview guideline. But not all the questions could be asked in the same manner as in the interviews, since a questionnaire only allows for brief explanation. Therefore, some questions were left out or adjusted. The questions have been discussed with several employees at NIVA and tested with a few people before actually running the questionnaire. The questionnaire was divided into three sections: 'general questions stormwater solutions', 'scoring stormwater solutions', and 'demographics'. It was originally developed in English but translated into Norwegian with help from a Norwegian intern at NIVA. This in order to reduce or eliminate possible language barriers. The questionnaire was online between 23 April 2019 and 6 May 2019, using Google Forms. It was spread via several Facebook pages, via own personal network and via the network of some interviewees. In total, 43 responses were received.

Phase 4: Ranking stormwater solutions

After scoring the different stormwater solutions, they were ranked by using Excel. Ranking the stormwater solutions can be done in several ways, such as: ranking with criteria weighting or ranking with ordered criteria. Within those ranking methods a wide variation is possible with respect to the selected weights and ordering (van Ierland et al., 2007). In this study criteria weighting is used, which means that weights are defined for each criterion that correspond with their level of importance. The final value for each stormwater solution is calculated by using weighted summations and is based on the given value and the weight for each criterion. This resulted in a ranking of the stormwater solutions. The overall ranking should not be considered as a final list, but rather as input for decision-makers. The purpose of the MCDA Framework is not to provide decision-makers with one best answer (Gough and Shackley, 2006), but to understand the explanation behind the scoring of experts and citizens. This decision matrix is complemented with information obtained during the interviews. The results of the citizens and experts were analysed and compared, which shows to what extent they have different perceptions of the selected stormwater solutions. However, since the citizens did not score on each criterion, it is not possible to equally compare all the results of the citizens and the experts.

Phase 5: Sensitivity Analysis

In the previous phase certain weights were used for the criteria in order to calculate the overall ranking of the stormwater solutions. However, using weights can influence the final ranking of the stormwater solutions (Garmendia and Gamboa, 2012). Therefore, a sensitivity analysis has been done to see if the outcomes would be different when using different weighting of the criteria. The analysis has been done by giving priority to one parameter while keeping the same weight for the other parameters (Martin, Ruperd, and Legret, 2007).

3.3 Identification of criteria

Several criteria can be used for scoring climate adaptation options. Multiple frameworks and papers have defined criteria that can be used (de Bruin et al., 2009; European Communities, 2009; Weiland et al., 2015). For the selection of criteria for this study it should be considered that experts as well as citizens are taken into account. Some of the criteria defined in literature have been selected for this analysis but are adjusted to conditions or existing policies in Oslo. For the selection of criteria it was important to aim for several qualities. The first one is completeness, which means that all the important criteria should be included. The second quality is redundancy, which implies that unimportant criteria or criteria where all the solutions will have the same score, should be deleted. Therefore, the criterion Climate mitigation was deleted because all the stormwater solutions do not score high on reducing Greenhouse Gas Emissions. Thirdly, the criteria should be operational, which means that it should be possible to assess the stormwater solution on each criterion. Fourthly, the criteria should be mutual independence of preferences when using weighted summations. This means that all the criteria are independent of each other and that scoring them is possible without knowing what the other scores are. The fifth quality is the number of criteria, since too many criteria can make communication about the results difficult. The last quality is that there should be no double counting of the criteria, because when there is double counting this effect gets more weight in the weighted summation. This last quality is not completely met, because the benefits and the side-effects overlap to some extent (Dodgson et al., 2009).

The stormwater solutions are scored on the following criteria:

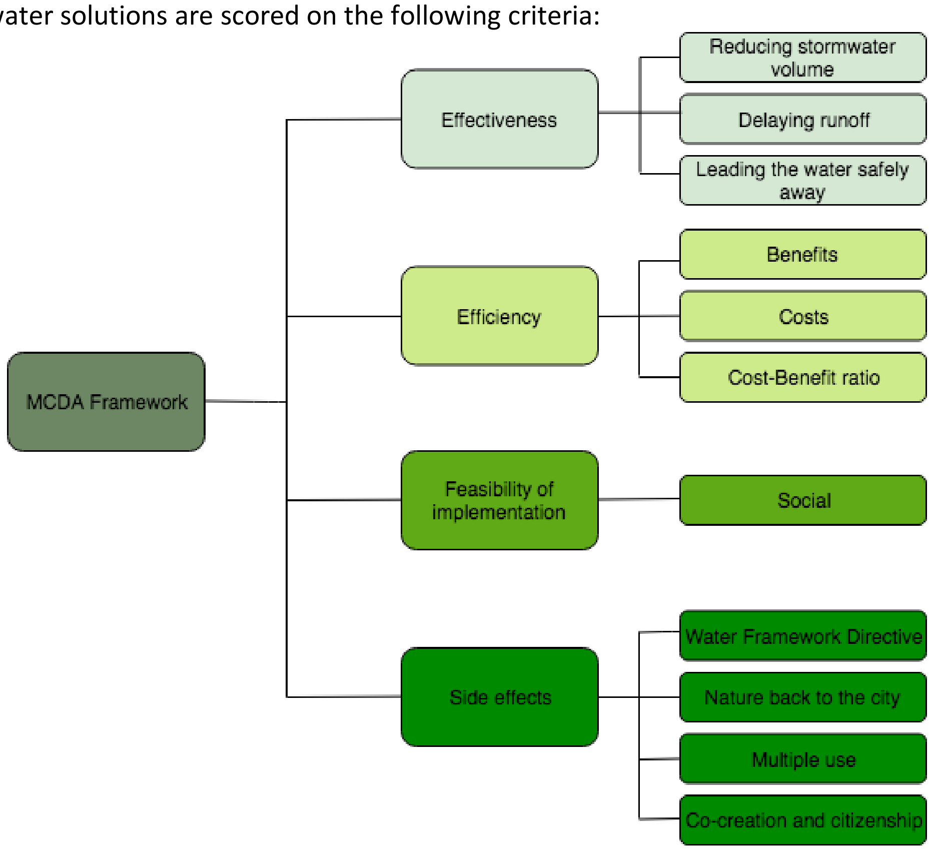

Figure 5. Criteria MCDA Framework

1. Effectiveness is defined as to which extent the stormwater solution can reduce the system's vulnerability to climatic change (Weiland et al., 2015) There are three sub-criteria based on the three-step strategy of Oslo municipality (Oslo kommune, 2016):

- **Reducing stormwater volume**: water can infiltrate after light rainfall.
- **Delaying runoff**: water is retained after moderate rainfall.
- **Leading the water safely away**: safe runoff to a recipient after heavy rainfall.

2. Efficiency looks into the economic viability of the stormwater solution by comparing its costs and benefits. A selected solution is efficient when the benefits outreach their costs (European Communities, 2009; Weiland et al., 2015).

- **Benefits:** benefits of the solution including direct benefits in terms of reducing stormwater problems and indirect benefits such as increasing the attractiveness of a neighbourhood.
- **Costs:** implementation costs of the solution.
- **Cost-Benefit ratio:** the benefits are compared with the costs, including long-term benefits and maintenance costs (Weiland et al., 2015).

3. Feasibility of implementation looks at certain barriers that can occur during the implementation of stormwater solutions (de Bruin et al., 2009; European Communities, 2009).

- **Social:** different values, opinions and perceptions can arise when implementing a stormwater solution (de Bruin et al., 2009; European Communities, 2009).

4. Side effects are often unintended positive or negative outcomes of the stormwater solutions which are not directly related to their first objectives of reducing stormwater problems (European Communities, 2009; Weiland et al., 2015). Several side effects are selected for this study:

- **Supporting the Water Framework Directive (WFD):** implementation of the solution contributes to objectives of the WFD, which implies a good qualitative and quantitative status for all water bodies in Europe (European Communities, 2009). Sustainable stormwater solutions can lead to a reduction of pollutants in the water (Lindh, 2013) and therefore also contribute to the Water Framework Directive.
- **Nature back to the city:** implementation of the solution contributes to making Oslo a greener city. As part of 'the kommuneplan for Oslo 2018' and in order to prepare the city for climate change, more green areas are planned in the city (Oslo kommune, 2018).
- **Multiple use:** the solution has multiple functions, such as increasing the attractiveness of the city, increasing the biodiversity, contributing to aesthetic or social achievements, or contributing to better public health.
- **Co-creation and citizenship:** the potential to involve citizens in the co-creation process of the solution. This relates to active involvement in the development, implementation and maintenance of services and activities related to the solutions. This comes from the idea that solutions should be created in collaboration between citizens, employees, volunteers, local organisations and across sectors. This improves the transparency of decision-making processes and foster trust, which increases the acceptance amongst the involved stakeholders (McKenna and Naumann, 2017).

The scoring of the stormwater solutions has been done by using the following criteria matrices. Those matrices show what each score, between 1 and 5, means for a specific criterion. The matrices differ between experts and citizens because the citizens did not score on each criterion. The experts were asked to score the solutions on a general basis in Oslo with their experience in stormwater management and the citizens to score the solutions based on their own preferences in their house and neighbourhood. It should be noted that the scoring is based on subjective opinions of the participants, based on their own values and expertise.

Table 1. Criteria matrix experts

Criteria	Sub-criteria	Score				
		1	2	3	4	5
Effectiveness	Three-step strategy	Solution has **no or a very low** effect on these steps	Solution has a **low effect** on these steps	Solution has a **medium** effect on these steps	Solution has a **high effect** on these steps	Solution has a **very high** effect on these steps
Efficiency	Benefits	Solution has **very low** benefits	Solution has **low** benefits	Solution has **medium** benefits	Solution has **high** benefits	Solution has **very high** benefits
	Costs	Solution has **very high** investment costs	Solution has **high** investments costs	Solution has **medium** investment costs	Solution has **low** investment costs	Solution has **very low** investment costs
	Cost-benefit ratio	Solution is **very costly** compared to its benefits	Solution is **costly** compared to its benefits	Costs are **equal** to its benefits	Benefits are **relatively higher** than costs	Solution has **great benefits** compared to its costs
Feasibility of implementation	Social	There is **strong opposition** from a lot of people against this solution	There is **opposition** from some people against this solution	There are **no major opinions** against this solution	There are more people **in favour** of the solution than against it	There is a **strong preference** for the solution, many people are in favour
Side effects	Supporting WFD	Solution has **no or a very low contribution** on achieving the WFD objectives	Solution has a **low contribution** on achieving the WFD objectives	Solution has a **medium contribution** on achieving the WFD objectives	Solution has a **high contribution** on achieving the WFD objectives	Solution has a **very high contribution** on achieving the WFD objectives
	Nature back to the city, Multiple use	Solution has **no or a very low contribution** on the side effect	Solution has a **low contribution** on the side effect	Solution has a **medium contribution** on the side effect	Solution has a **high contribution** on the side effect	Solution has a **very high contribution** effect on the side effect
	Co-creation and citizenship	Solution has **no or very low potential** to involve citizens	Solution has **low potential** to involve citizens	Solution has **medium potential** to involve citizens	Solution has **high potential** to involve citizens	Solution has **very high potential** to involve citizens

Table 2. Criteria matrix citizens

Criteria	Sub-criteria	Score				
		1	2	3	4	5
Efficiency	Benefits	Solution has a **high negative effect** on the housing price	Solution has a **negative effect** on the housing price	Solution has **no effect** on the housing price	Solution has a **positive effect** on the housing price	Solution has a **high positive** effect on the housing price
	Costs	I would **very much not like** to contribute	I would **not like** to contribute	No opinion	I would **like to** contribute	I would **very much** like to contribute
Feasibility of implementation	Social	**Extremely unhappy** with the solution	**Unhappy** with the solution	**No opinion** about the solution	**Happy** with the solution	**Extremely happy** with the solution
Side-effects	Nature back to the city	Solution has **no or a very low contribution** to bringing nature back to the city	Solution has a **low contribution** to bringing nature back to the city	Solution has a **medium contribution** to bringing nature back to the city	Solution has a **high contribution** to bringing nature back to the city	Solution has a **very high contribution** to bringing nature back to the city
	Multiple use	Solution has **no or a very low contribution** on creating multiple functions	Solution has a **low contribution** on creating multiple functions	Solution has a **medium contribution** on creating multiple functions	Solution has a **high contribution** on creating multiple functions	Solution has a **very high contribution** on creating multiple functions
	Co-creation and citizenship	I would have **no or a very low motivation** to be involved	I would have a **low motivation** to be involved	I would have **medium motivation** to be involved	I would have a **high motivation** to be involved	I would have a **very high motivation** to be involved

Chapter 4 Results

For the MCDA, it was needed to select stormwater solutions. Therefore, an overview of the stormwater solutions was created in 4.1. From that, I made a ranking of the most appropriate solutions for the Oslo region (section 4.2). During this scoring several challenges of stormwater management in Oslo came to front, discussed in 4.3. Furthermore, a sensitivity analysis is done to see how robust the results are.

4.1 Identification of stormwater solutions

For the Multi-Criteria Decision Analysis, it was needed to select certain stormwater solutions. The selection of the solutions is based on literature research. There are different types of stormwater solutions, all with the purpose to prepare a city to better deal with flooding. This study investigates conventional, sustainable and socio-economic solutions.

In cold climates several aspects should be taken into account when selecting stormwater solutions. Multiple challenges arise: such as a high fluctuation of temperatures in a short period of time, freeze-thaw cycles and fluctuation in the amount of precipitation (Andenæs et al., 2018). As described earlier, in many cities green solutions are added to the current grey infrastructure, to make the system more sustainable and to reduce the amount of stormwater that goes into the underground system (Church, 2015).

An overview of the selected solutions is given below:

Figure 6. Bioswales

Figure 7. Street gutters

1. Bioswales are open vegetated water systems that handle stormwater. The water flows through a layer of vegetation and infiltrates in the underlying soils. These systems also have the possibility to store snow (Friends of the Greenbelt Foundation, 2017; Jotte et al., 2017; Martínez, 2016).
2. Street gutters carry water to the next waterbody or to the underground drainage system.

Figure 8. Dry detention basins

3. Dry detention basins only store water during heavy rainfall and hold the water until the flood risk is gone. Afterwards, the water is discharged to a water body or channel system. They are often covered with grass (Wagner and Krauze, 2014).

Figure 9. Reopening streams and rivers

4. Currently most waterways are closed inside pipes. However, enclosed rivers have a limited capacity to handle stormwater. By reopening parts of streams and rivers it becomes possible for rivers to manage water better during extreme rainfall (European Green Capital, 2019).

Figure 10. Disconnection of downspouts

Figure 11. Rain barrels

5. By disconnecting the downspouts from the sewage system, flooding in the basements can be prevented. The water will drain into the surrounding gardens and lawns.

6. Rain barrels can be used by households to store rainwater from the roof and this can be used for gardening. The total amount of stormwater runoff that otherwise discharges into surface is reduced (USEPA, 2007; Friends of the Greenbelt Foundation, 2017).

Figure 12. Permeable pavements

7. Water runoff infiltrates through permeable pavements to pipes or the underlying soil. The pavements look similar to regular ones but they are built in such a way that they leave space within

the pavements. Due to permeable pavements, total water runoff declines and the water quality improves by filtering the water (Friends of the Greenbelt Foundation, 2017; Jotte et al., 2017).

Figure 13. Trees

8. Trees catch and absorb rainwater, evaporate water, provide shades, and increase the biodiversity in the city (Kabisch et al., 2016; Wagner and Krauze, 2014).

Figure 14. Rain gardens, rain beds and planter boxes

9. The water can infiltrate through the plants in a rain garden, rain bed or planter box (Friends of the Greenbelt Foundation, 2017).

Figure 15. Extensive and intensive green roof

10. Green roofs are nature-based solutions that consists of vegetation installed on roofs. The stormwater is absorbed and stored temporarily. The vegetation will absorb and evaporate the water and this solution will lead to a reduction of the stormwater runoff into the water system (Andenæs et al., 2018; Friends of the Greenbelt Foundation, 2017; Jotte et al., 2017; Martínez, 2016; Wagner and Krauze, 2014). There are two types of green roofs:

- **Extensive roofs:** these green roofs have a low substrate depth and the plants have shallow roots. The maintenance is easy, and the roofs are usually not accessible. An example is given in the left picture.
- **Intensive roofs**: these green roofs have a large substrate depth and the plants have deep roots. Maintaining the roofs can have significant cost and irrigation systems are often necessary. The

roofs can be used for recreational purposes and are often accessible for people (Andenæs et al., 2018; Martínez, 2016). An example is given in the right picture.

11

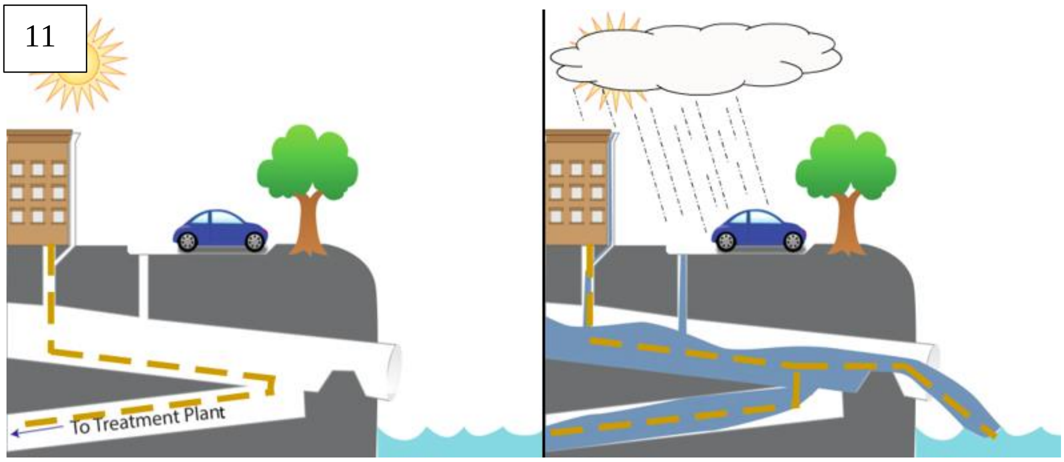

Figure 16. Combined sewer system

11. A drainage pipe system is the traditional way of handling sewage and stormwater. The stormwater is disposed into the drainage system and drains to the centralised wastewater treatment (Newman et al., 2013).

12. Public awareness about stormwater
In order to create a more climate proof water system the implementation of stormwater solutions is not solely limited to technical solutions, but also implies non-structural options. Creating public awareness by for example education or information campaigns helps in making residents more aware about alternative ways of managing stormwater (Wagner and Krauze, 2014).

13. Public financial support
Some stormwater solutions can be implemented by households and therefore providing financial support for such solutions can help to increase the number of implemented solutions.

4.1.1 Additional stormwater solutions

For this study 13 stormwater solutions have been analysed. This is not a complete list, since there are more stormwater solutions that could be implemented in cities. Additional solutions that were mentioned a few times by interviewees are: floodways (Interview 1, 3), green walls (Interview 5, 15, 21) and wetlands (Interview 5, 13). Floodways lead the water away (Interview 3) and their primary purpose is different, e.g. roads that can be used as a floodway (Interview 1). Green walls are a good solution in dense cities (Interview 21). Ideal situation would be if the water is detained on a green roof and then guided to a rain garden, so that it is combined with other stormwater solutions. This can take up a lot of water while using little space (Interview 15). Another solution mentioned by a citizen is for people to act when flooding occurs, such as an evacuation plan (Interview 8).

4.2 Ranking stormwater solutions

Ranking stormwater solutions can be done with or without using a weight factor. Equal weights are used for the analysis of the experts, interviewed citizens and the citizens of the questionnaire. This because the interviewees found it hard to define the importance of the criterion in a percentage. Next to this, there was no clear consensus amongst them about the prioritisation of the criteria.

Many experts emphasised the fact that the scores of the stormwater solutions are site dependent (Interview 1, 2, 3, 5, 10, 12, 13, 15, 17, 18, 20, 21). Even one of the interviewees mentioned that it was not possible to give scores at all (Interview 10). How the solutions score on the selected criteria depends, among other things, on the soil properties and the characteristics of the surrounding area people (Interview 10). It is important to understand how site dependent stormwater solutions are. In order to deal with this, some interviewees gave two scores or a range of scores for certain aspects because according to them it was not possible to define one score (Interview 1, 2, 3, 6, 8, 12, 13, 17, 18, 20, 21). For those scores the average is taken for the calculations of the overall ranking.

The following tables give an overview of the ranked stormwater solutions. In the column 'weighted sum' the final score is given together with the final ranking in brackets. The weighted summations of the scores for each criterion define the final ranking of the stormwater solutions. Three tables are shown: one of the interviewed experts, one of the interviewed citizens and one of the citizens of the questionnaire. The latter two are presented separately because the interviews provided additional information. During the interviews more extensive explanation was possible, which could result in a better understanding of the stormwater solutions and criteria. Furthermore, during an interview people take more time to fill in the scores than during a questionnaire.

Table 3. MCDA Experts (n=15)

Nr.	Stormwater solutions	Criteria											
		Effectiveness			**Efficiency**			**Feasibility of implementation**	**Side effects**				**Weighted sum**
		Reducing stormwater volume	Delaying runoff	Leading the water safely away	Benefits	Costs	Cost-benefit ratio	Social	Supporting WFD	Oslo green city	Multiple use	Co-creation and citizenship	
1	Bioswales	4.0	3.6	4.0	4.3	3.2	4.1	3.5	4.5	4.4	3.9	3.4	**3.9** (5)
2	Street gutters	1.1	1.1	3.6	2.6	4.0	3.1	3.5	1.2	1.3	1.2	1.3	**2.2** (10)
3	Dry detention basins	3.8	4.6	1.9	4.1	2.8	4.1	3.8	3.0	3.3	4.2	3.9	**3.6** (7)
4	Reopening parts of streams and rivers	2.6	3.1	5.0	4.7	1.8	4.4	4.3	3.7	4.8	4.8	4.0	**3.9** (1)
5	Disconnection of downspouts	3.5	2.9	2.2	3.8	4.9	4.6	3.5	3.4	2.4	2.1	3.7	**3.4** (9)
6	Rain barrels	2.6	3.1	1.5	3.4	4.6	3.9	3.4	2.3	2.2	2.8	4.4	**3.1** (8)
7	Permeable pavement	3.8	3.0	2.1	3.6	3.8	4.2	3.3	3.0	2.4	2.6	1.8	**3.1** (6)
8	Trees	3.7	2.5	1.3	4.4	3.5	4.3	4.3	3.3	4.9	4.5	3.7	**3.7** (2)
9	Rain gardens / Rain bed / Planter boxes	4.5	4.2	1.8	4.4	3.0	3.9	3.9	4.4	4.5	4.1	3.8	**3.9** (3)
10	Green roofs	3.4	3.3	1.4	3.9	3.1	3.7	4.1	3.2	4.5	4.0	3.8	**3.5** (4)
11	Underground solutions such as pipe system	2.1	2.6	2.7	2.6	1.6	2.0	3.1	1.4	1.1	1.0	1.0	**1.9** (11)

Some of the experts did not score the stormwater solutions on each criterion (Interview 2, 3, 6, 13, 17, 20). For example, some interviewees did not score on the costs or cost-benefit ratio because they acknowledged to not have sufficient knowledge on those criteria. This means that those criteria are based on less scores.

Table 4. MCDA Interviewed citizens (n=8)

Nr.	Stormwater solutions	Criteria						
		Efficiency		**Feasibility of implementation**	**Side effects**			**Weighted sum**
		Benefits	Costs	Social	Nature back to the city	Multiple use	Co-creation and citizenship	
1	Bioswales	4.0	2.9	4.5	4.2	3.3	2.9	**3.6** (5)
2	Street gutters	3.3	1.4	3.6	1.4	1.6	1.4	**2.1** (10)
3	Dry detention basins	3.3	2.0	3.8	2.9	2.9	2.0	**2.8** (7)
4	Reopening streams and rivers	4.5	3.8	4.5	4.9	4.4	3.8	**4.3** (1)
5	Disconnection of downspouts	3.1	2.1	3.3	2.0	1.5	2.1	**2.4** (9)
6	Rain barrels	2.6	2.8	3.1	1.8	2.5	2.8	**2.6** (8)
7	Permeable pavement	4.3	2.5	4.9	2.8	2.9	2.5	**3.3** (6)
8	Trees	4.3	3.5	5.0	4.9	4.0	3.5	**4.2** (2)
9	Rain gardens / Rain bed / Planter boxes	4.4	3.5	4.9	4.6	3.8	3.5	**4.1** (3)
10	Green roofs	4.1	3.8	4.1	4.4	4.0	3.8	**4.0** (4)
11	Underground solutions such as pipe system	3.6	1.1	3.8	1.5	1.4	1.1	**2.1** (11)

Table 5. MCDA Questionnaire citizens (n=43)

Nr.	Stormwater solutions	Criteria						
		Effiency		**Feasibility of implementation**	**Side effects**			**Weighted sum**
		Benefits	Costs	Social	Nature back to the city	Multiple use	Co-creation and citizenship	
1	Bioswales	3.4	3.3	4.5	4.2	3.7	3.2	**3.7 (5)**
2	Street gutters	2.7	2.2	3.4	1.9	2.2	1.6	**2.3 (9)**
3	Dry detention basins	2.8	2.5	3.4	2.4	3.1	2.4	**2.8 (7)**
4	Reopening streams and rivers	4.0	3.6	4.4	4.5	4.4	3.9	**4.1 (4)**
5	Disconnection of downspouts	2.6	2.3	3.2	2.1	2.2	1.6	**2.3 (10)**
6	Rain barrels	2.7	2.6	3.4	2.2	2.5	2.4	**2.6 (8)**
7	Permeable pavement	3.0	2.6	3.8	3.0	2.9	2.7	**3.0 (6)**
8	Trees	4.1	3.9	4.7	4.7	4.4	4.1	**4.3 (1)**
9	Rain gardens / Rain bed / Planter boxes	4.1	3.8	4.5	4.5	4.3	4.0	**4.2 (2)**
10	Green roofs	4.2	3.9	4.4	4.5	4.2	3.8	**4.2 (3)**
11	Underground solutions such as pipe system	2.8	2.2	3.3	1.9	1.0	1.5	**2.3 (11)**

From the Tables 3-5, it becomes clear that experts and citizens rank green solutions higher than the traditional or grey solutions. Trees (8) score highest in the questionnaire, where reopening parts of streams and rivers (4) score highest by experts and interviewed citizens. The maintenance of some stormwater solutions is important because it makes the solution more expensive. For those solutions it could help to involve citizens in the design, implementation or maintenance. The degree of citizen involvement often depends on the awareness level of the citizens of stormwater challenges in Oslo. This awareness also depends on the feasibility of implementation. When people understand why solutions are needed and how they function, they are less likely to be against the implementation of the solution and also more willing to be involved. A high score on the multiple use criterion usually coincide with a high score on the feasibility of implementation. Those solutions are also applicable to other issues (e.g. recreation) apart from handling stormwater, which makes people more satisfied with its implementation. Furthermore, the solutions that score high on multiple use also score high on co-creation and citizenship. In the next section each criterion will be further looked at. As such, more insight is obtained on why some solutions score high and others low.

4.2.1 Effectiveness

The effectiveness criterion is only scored by experts since it is difficult to score the stormwater solutions on their effectiveness without any background knowledge. How effective the stormwater solutions are depends on the context (Interview 18), such as available space (square meters) used for the solution (Interview 18, 21, 15), characteristics of the surrounding area (Interview 2, 17), the climate (18) and soil properties like soil type and infiltration capacity (Interview 15). Overall, stormwater solutions are more effective when they are combined (Interview 15, 21). For instance, when a green roof is combined with a disconnected downspout (Interview 12).

Table 3 shows that green solutions score high on effectiveness but cannot handle heavy rainfall (Interview 5). In contrast, pipe systems rank lowest. Their capacity is limited and they only work well up to a certain threshold value (Interview 17, 18, 21). Moreover, pipes may fill up with gravel and waste, which further limits their capacity (Interview 12). Consequently, pipe systems do not safely lead the stormwater away (Interview 6, 19). So, this solution will never have the capacity to solve stormwater problems (Interview 21). However the system is needed as a back-up (Interview 18).

4.2.2 Efficiency

Several interviewees mentioned the importance of maintenance costs (Interview 1, 12, 18, 20). When green solutions are implemented they are often aesthetically pleasing. However as time passes they can start to show signs of degradation (Interview 19). Permeable pavement, dry detention basins, intensive green roofs and bioswales can have high maintenance costs (Interview 1). Overall, open vegetated systems are easier to maintain because they are visible (Interview 2). However, not much is known about the maintenance costs of green solutions since there is not much knowledge about the life expectancy of the solutions (Interview 2). Another important factor that should be taken into account is the land cost (Interview 12, 15, 19). This especially is important in urban areas because there is not much space. Implementing stormwater solutions is a question of priority, since the space could also be used for other purposes (Interview 18).

The decision matrix of the experts shows that green solutions score high on the benefits criterion, in particular reopening streams and rivers, rain gardens and trees. One expert mentioned that solutions with benefits in addition to climate adaptation are valued high (Interview 5). Those benefits are related to the multifunctionality, health, aesthetics and the biodiversity (Interview 17). In order to create high benefits it is important to use good materials and to think in the long-term when building a public space (Interview 10). For urban developers the design is important. Solutions with a good design score higher on the benefits (Interview 6). People appreciate a well-designed solution and will more likely use it (Interview 10). Considering the costs, drainage pipe systems are overall more expensive because construction work underground brings along high costs (Interview 2). Most solutions score high on the cost-benefit ratio, with lower scores for the pipe system and street gutters. One expert mentioned that green solutions have a high cost-benefit ratio (Interview 5), which means that the benefits outweigh the costs.

Table 4 and 5 show that citizens scored green solutions also high on the benefits criterion. Apparently, citizens think that these may have a positive effect on their housing prices. Solutions that have high scores on the cost criterion are reopening streams and rivers, green roofs, trees and rain gardens. This means that for green solutions citizens are willing to partly pay, help with implementation or the maintenance. Which results in a reduction of the amount of public funding spent (e.g. from Oslo municipality) and is especially interesting for reopening streams and rivers, because this is a costly solution.

Some specific costs and benefits that are discussed during the interviews are further described below. Bioswales and dry detention basins require a lot of space (Interview 1, 2, 12, 18), which could otherwise be used as parking spaces for example (Interview 1). Bioswales are relatively cheap (Interview 12, 18), while the benefits are high because of their multifunctionality: They can store snow, handle stormwater and are aesthetically attractive. So, even though quite a lot of space is needed, the solution is still worth using (Interview 12). Reopening rivers is expensive and it requires a lot of planning (Interview 2, 10, 12, 15, 18, 19, 20) but it has high benefits (Interview 6, 12). This solution has a positive effect on the housing prices (Interview 9, 18) and is used by housing companies as a selling point

(Interview 9). Another very costly solution is a pipe system (Interview 6, 18, 4, 12, 19). The benefits are high in reducing the stormwater volume if the pipes are big enough but low in terms of something that is attractive for the people (Interview 15, 17). It is unpredictable how this solution functions because the pipes are underground. Which makes it harder to monitor (Interview 6).

4.2.3 Feasibility of implementation

Opposition can arise when implementing stormwater solutions (Interview 1, 5). Especially all solutions that are on the surface are subject to opposition since implementation requires land (Interview 2). There is often quite some opposition from developers and house-owners about stormwater solutions (Interview 15). The municipality and urban planners have many things to consider when making plans, so do not only think about handling stormwater but also about social-economic issues for example. (Interview 21). Citizens are in general happy when flooding is handled, but currently, many citizens prioritise removing green areas to create space for parking lots (Interview 21).

Some experts pointed out that the feasibility of implementation depends on whether the solution is implemented on public or private ground (Interview 3, 10, 13, 20). The experts have different experiences when it comes to the implementation of stormwater solutions. One of the experts experiences that citizens tend to be less negative if the solution is implemented on a public property. However, this differs for private ground, since in Norway the ownership of the properties is very established. Therefore, people will in general be negative if the municipality is suggesting having some solutions on the private properties and very positive if it is on public land (Interview 13). While another expert experiences that the tendency is when plans are made for stormwater solutions, that citizens are negative. Beforehand they are in doubt if the solutions would be a positive contribution to the neighbourhood. However, when the solution is completed, people are often satisfied with what they see (Interview 21). Furthermore, another expert experiences that if the solution contributes to a more blue-green environment, people are in general positive (Interview 19). The opinion of tenants is also dependent on what people know about stormwater (Interview 21). This relates to the fact that the feasibility depends on the learning factor: People that understand better why the stormwater solutions are needed and how they function, are less likely to be against its implementation (Interview 5). The feasibility also depends on the functionality of the solution. For instance, if there is a higher functionality by combining certain functions, the solutions are much more appreciated. So, it is important to look for stormwater solutions that have a higher functionality and a higher usability. For example, a rain garden combined with permeable pavement that could also be used as a parking lot. Those solutions are the future, because in populated areas there is not enough space. When the solution has multiple functions the level of acceptance of the people increases (Interview 15).

When it comes to the feasibility of implementing specific stormwater solutions, opinions may strongly differ (Interview 5, 6). Some of those cases will be discussed here. For example, reopening parts of streams and rivers can be part of big discussions (Interview 1, 6, 18). On the one hand, some actors are against reopening rivers because this is a costly solution and the space and money can be used for other purposes (Interview 1, 5). Developers often are sceptical as it is costly, it takes up space (Interview 6) and it requires maintenance (18). Several experts experienced that citizens are scared that their children will drown in the open water (Interview 1, 3, 21) or that they are afraid of flooding (6). On the other hand, citizens are in favour of rivers (Interview 4, 8, 9, 14, 15, 16) because it provides nature (Interview 3) and the area can be used for recreation (Interview 6). One of the citizens mentioned that this solution improves the living quality (Interview 8).

Regarding trees there are also mixed feelings (Interview 1, 7, 18). Some citizens are against this solution because of the shade (Interview 1) and are afraid that it might block their view (Interview 20). One expert mentioned that it is often experienced that people try to cut down the trees (Interview 20). However, some citizens are in favour because trees make a neighbourhood more attractive

(Interview 1, 4, 14, 16), thereby increasing the housing prices. Moreover, they have many other co-benefits: bringing biodiversity into a neighbourhood (Interview 16), assimilating carbon dioxide, reducing air pollutant concentrations (Interview 1) and providing recreation possibilities (Interview 8).

Furthermore, rain barrels and disconnection of downspouts can also lead to resistance of people if they are near to their living spaces (Interview 15). The decision matrix of the interviewed citizens shows that the feasibility of implementation is lowest for those two solutions. One citizen mentioned that disconnection of downspouts would be more effective in the countryside where the water can go into a garden (Interview 16). Another citizen mentioned that during heavy rainfall, there is a lot of water in the streets coming from disconnected downspouts and therefore, she did not like this solution (Interview 14). One of the citizens had first disconnected downspouts going into her garden, but they re-connected the downspouts because the garden became too soaked (Interview 9). In contrast to the citizens, disconnection of downspouts is by some experts seen as an effective, easy and cheap solution (Interview 1, 5, 12). Which can be implemented by people themselves (Interview 1, 12, 14, 18, 19) and supports in the learning process about stormwater solutions (Interview 5). When considering rain barrels, some citizens were in favour (Interview 9, 11). One interviewee mentioned that she was willing to organise a workshop to show how you can make them look attractive, how to implement them and to show people why the solution is needed (Interview 9). On the other hand there were citizens that did think the opposite because they dislike the aesthetics of rain barrels (Interview 4, 8, 11) and they take up space (Interview 16). People also put question marks regarding necessity, because Oslo is not a city in need of water and that there is good drinking water (Interview 3, 16, 18).

Another solution at which opinions differ widely is that of permeable pavement. This mainly relates to the maintenance costs. However, no clear consensus exists among the interviewed experts. Several experts mentioned that the quality of permeable pavements will decrease over time (Interview 18, 20). This because dirt, sand, and other particles fill the small holes that make them less permeable (Interview 10, 20). Therefore, maintenance is required (Interview 6, 17, 18, 20). Experts in favour say that the solution is good for solving stormwater problems (Interview 6). There are not many places in Oslo where this solution is implemented, because they are not tested yet (Interview 12). One expert mentioned that this is because the municipality is conservative. They prefer solutions that already proofed to work: so that they know the prices, how to implement it, all the functions and all the possible problems. The municipality is scared to take risks because they use citizens' money and that should be used in a good way. They want to be safe in what they do and testing new solutions can cause problems (Interview 12). Another expert that has experience with permeable pavement explained that the effectiveness will decrease with time, but that it stabilises at 10-20% of the original capacity without maintenance. In his opinion, the opposition is more about the scepticism that it does not look new and that there can be a little bit of rainwater standing in the area. If this is accepted, there are a lot of benefits. The fine material in the upper 2 cm can function as a sand filter that filters polluted water, but this needs to be tested to fully understand how it works (Interview 15).

The three-step strategy of Oslo municipality is integrated in the planning system and it is accepted that planners are supposed to deal with open surface solutions (Interview 6). One expert mentioned that the green solutions should complement the traditional systems, and the traditional system should support the open surface solutions and function as back-up (Interview 18). However, some developers think short-term and therefore prefer pipe systems (Interview 6). When considering the feasibility of the drainage pipe system, it has been mentioned by experts that people do not have much of an opinion about it since it is underground and invisible (Interview 1, 12, 15). Besides, people are used to it (Interview 18) and satisfied with the underground pipes (Interview 10, 14, 22). However, it was mentioned that it is a really expensive solution (Interview 8, 11, 14) since it will take years to construct (Interview 8). Nevertheless, a city could not function without it (Interview 7, 22). One of the citizens said that in the long-term drainage pipes are the best solution, because they handle the stormwater underground (Interview 14). Others were in favour of green solutions and said that if those solutions work well bigger pipes are not needed (Interview 8, 11). However, it would be a worthy investment if the amount of water is so large that bigger pipes are needed (Interview 11). The decision matrices of the citizens show that pipe systems do not score very low on the feasibility of implementation, whereas those systems are scored as lowest by the experts.

4.2.4 Side effects

Water Framework Directive

This aspect also is only scored by experts, since background knowledge is needed. Several experts mentioned aspects that define high scores for supporting the WFD: solutions that are green and that transport the water (Interview 5); solutions that delays the runoff (Interview 12); solutions that lead water onto green surfaces (Interview 21); and all the solutions with infiltration have some effect on the WFD (Interview 20). One of the experts pointed out that the flooding aspect of the stormwater solutions should be combined with pollution aspects. Pollution should be emphasised more and should become a combined assessment (Interview 19).

There are several stormwater solutions that support the objectives of the WFD. Bioswales have a very high effect (Interview 17) and are therefore scored as highest. Rain gardens, planter boxes and rain beds are also scored high. The water can infiltrate in a dry detention basin when green surfaces are used (Interview 18, 21). However, wet detention basins would have a higher contribution to the WFD especially when connected to a sewage system (Interview 19). Vegetation on the side of a river also support the WFD (Interview 18, 19).

Nature back to the city

One expert mentioned that most of the selected solutions are in line with the nature back to the city requirements of Oslo municipality, except the pipe system and street gutters (Interview 13). Solutions that scored high by expert and citizens are: rivers, since it is a big green solution and has a very large visual quality; trees; green roofs; rain gardens; and bioswales.

Multiple use

In general, a solution is more interesting when it has more functions (Interview 5, 10, 12, 17). Multifunctional solutions are in favour considering the lack of space in a city (Interview 12). Some solutions are more than only a stormwater solution; reopening streams and rivers is the leading example (Interview 10, 13). This solution is therefore scored as highest by the interviewed citizens and experts. Rivers provide a good living quality for people. Some experts mentioned that the side effects of this solution are even more interesting than its main purpose of handling stormwater (Interview 10, 17). Green roofs, rain gardens and trees also have high scores (Interview 5). Different multiple use aspects were mentioned: aesthetics (Interview 2, 14, 16, 19, 22, questionnaire), recreation (Interview 2, 6, 19), creating public awareness (Interview 2), good for insects (Interview 22, questionnaire), improving the air quality, that it can be used as a playground (Interview 3) which can be used to teach children about the solutions (questionnaire), increasing health (Interview 3, 6, 10, 17, questionnaire), and providing social meeting places (Interview 17). “Adding such places of peace and quiet makes the city more attractive. People can enjoy the plants and trees. It gives the feeling of being connected more to the nature. Those places offer the opportunity for the community to gather” (questionnaire).

Co-creation and citizen engagement

Citizen engagement is important because it shows who is going to maintain the solution (Interview 2). Experts mentioned that solutions with a positive contribution to a neighbourhood score high (Interview 5). Multipurpose solutions that are not on large-scale and affect the local environment have the highest potential to involve citizens (Interview 6). Pointed out by experts during the interviews is that disconnected downspouts (Interview 18), rain barrels (Interview 18), rain gardens (Interview 2) and green roofs (Interview 2) have high potential to involve citizens. The expert decision matrix indeed shows that those solutions score high. Other solutions scoring high are reopening parts of streams and rivers, dry detention basins, disconnection of downspouts and trees. Experts scored rain barrels as the solution with the highest potential for co-creation. Since rain barrels empower people, it gives them the idea that they can implement it themselves (Interview 10). Citizens also gave high scores to reopening parts of streams and rivers, green roofs, rain gardens and trees. While in contrast to the experts, they gave disconnection of downspouts and rain barrels lower scores. This is an interesting finding, as it shows a different perception of which solutions have potential for citizen involvement. This could be explained by the fact that citizens gave those solutions lower scores for feasibility of implementation than experts did. The majority of citizens do not see the necessity of those solutions and are less positive about becoming involved.

Several aspects that are important for citizen engagement were mentioned during the interviews. The main problem of stormwater solutions is the maintenance. People are needed to maintain the solutions, otherwise some solutions do not function well (Interview 22). As recommendation it was mentioned that most solutions work when the public is responsible for taking care of the solutions. However, only the minority is interested in co-creation. It is hard to get people actively involved (Interview 20). There is higher motivation to be involved in solutions that will reshape or restructure the neighbourhood (Interview 4). However, the motivated people are often a group that have the time, energy and the capacity to be there (Interview 10). Therefore, it is good to have a 'neighbourhood director', someone who is responsible for the bigger picture and who makes sure the citizens are involved (Interview 10). One of the citizens described that involvement is also dependent on the perception on who is implementing the solution. When someone in a uniform fulfils the implementation or maintenance, citizens believe that they are not qualified to do it themselves. It is important to show drawings on how to implement the solution in real life (Interview 11). Currently, people are usually not asked to be involved. Oslo municipality just uses their own knowledge and expertise. While citizens could help with thinking about the solutions. However, at the same time people do not really care, dugnad (common maintenance efforts in Norway) is disappearing. One of the experts mentioned that it could help to organise an event or that people get a fine when they do not show up at meetings (Interview 20). Another expert mentioned that a good procedure of co-creation would be to see who is using the space. Then start to invite the people and to make clear what the possibilities are (Interview 10). Even though citizen engagement is seen as important by most experts, one of the experts mentioned that co-creation is not that important when there is high social acceptance about the solutions (Interview 3). Another expert mentioned that co-creation is not always a good thing; cities are complex systems and especially in urban areas a thorough understanding of the conditions of the site is needed (Interview 10). This relates to the point mentioned by a citizen: that some solutions are more suitable for the government or experts to handle (Interview 4).

4.2.5 Public awareness and public financial support

Besides the technical solutions, this study also investigates two socio-economic solutions: public awareness and public financial support. After a few interviews it became clear that it is difficult to score those solutions on the selected criteria since it is hard to say how effective or costly those solutions are. Therefore, instead of giving scores, those solutions were only discussed.

Several experts acknowledged the importance of raising awareness about stormwater challenges among the public, developers and urban planners (Interview 1, 2, 3, 5, 6, 18, 20). Political willingness to change the rules is needed (Interview 18). Politicians therefore have to see the importance of handling stormwater on the ground (Interview 20). It is important to think about how to communicate, showing why the stormwater solution is necessary (Interview 2). It helps when people understand what is going on when stormwater solutions are implemented (Interview 5). When people become aware of the changing climate, they realise that the water needs to be handled locally on their own ground and they start to become creative themselves (Interview 3, 21). Creating public awareness can be done by i) education programs (Interview 1, 5, 18), ii) awareness campaigns (Interview 1) that communicate about the risks of climate change (Interview 6), iii) information signs and pictures in parks that explain what the solutions are and how they function, iv) brochures from the municipality (Interview 5), v) economic tools such as creating incentives with taxes (Interview 18), vi) seeing real examples (Interview 5, 20), vii) and surveys or e-mails (Interview 1). Especially learning is an important factor when it comes to public awareness (Interview 5). For example, one participant of the questionnaire mentioned that she learned a lot about stormwater solutions when filling in the questionnaire of this study. It was also pointed out that besides spreading information, there should be clear and more specific demands from the municipality on what is required for the area (Interview 20). The municipality plan should have clear rules about the use and maintenance (Interview 18). The Oslo municipality plan could have been more specific about stormwater handling, since currently it is very flexible (Interview 20). However, a mentality change is already happening in Oslo, now it has to be translated into clear rules for financing and decision-making (Interview 18). One of the experts mentioned that public awareness is especially important for people who construct houses and landscape architects. They will more likely consider stormwater issues in their plans when they are aware (Interview 3).

Considering the awareness level of the interviewed citizens, most of them do not see flooding as a problem in Oslo (Interview 4, 8, 14, 16). However, some of them mentioned that it is a problem in other parts of Norway (Interview 8, 14, 16). Most citizens of the questionnaire filled in that it is very unlikely or unlikely that their basement or house will be flooded in the coming 10 years. While most citizens think it is very likely that the streets in Oslo will be flooded in the coming 10 years (Appendix V). Only one of the interviewees experienced issues caused by stormwater in her basement and garden (Interview 9). While several citizens of the questionnaire experienced water in their basements because of heavy rainfall. Some interviewees and citizens of the questionnaire mentioned that they experienced water on the streets in certain areas in Oslo during heavy rainfall (Interview 7, 8, 14). Another point that was made is that instead of experience with too much stormwater, there were problems with shortage of water during the summer (Interview 11, 16). On municipality level, stormwater has been given more priority. Politicians, the municipality and people have recognised that this is a big issue, since many basements have been flooded and it rains more and more heavily (Interview 12). One of the experts experiences that companies are becoming more aware, since more green solutions are implemented than before (Interview 20).

However, it takes a lot for people to actually do something themselves. If people do not have a problem with water, people are less likely to install stormwater solutions themselves (Interview 6). Therefore, public financial support could help. Some experts mentioned that this only works if it is connected with high public awareness, since with a low awareness level people still do not see the need to implement a solution themselves (Interview 3, 5). While on the other hand another expert mentioned that public financial support will make people more aware. When seeing the solutions at their neighbours they become curious and therefore also more aware of what the solutions are and how they function (Interview 21). Another important point is the organisation: will the municipality bring the solution to the people or do they need to buy it themselves? And which information, help, practical realisation or guidelines will be provided? (Interview 3) Stormwater solutions that could be supported with financial support are for example green roofs, rain gardens, disconnection of downspouts and rain barrels (Interview 3).

Some of the interviewed citizens said that they would be interested to install certain stormwater solutions themselves with financial support (e.g. green roofs or rain barrels) (Interview 11, 14, 22). However, it also depends on how it is organised (Interview 14, 16) and for what kind of solution the support is provided (Interview 22). Citizens prefer when the implementation of a solution is organised in group context (Interview 14, 16).

4.2.6 Additional Criteria

The interviewees were asked to address additional criteria, some are described here. Earlier it was described how site dependent stormwater solutions are. Therefore, several experts pointed out that the context is missing (Interview 2, 18). It is important to know what the starting point of the area is to see which stormwater solutions are needed (Interview 3).

The importance of maintenance has been addressed before and is included in the Cost-benefit criterion. Some experts mentioned that there should have been more focus on this aspect (Interview 3, 15, 19). It should for example be scored on how stormwater solutions behave over time (Interview 3, 6). Another criterion that could have been emphasised more is the Feasibility of implementation (Interview 5, 6). This could look more into the social differences (Interview 6), level of conflict between the different actors (Interview 6) and make a distinction between private and public ground (Interview 3, 13, 20).

Other points that were mentioned by experts are: visibility, since this makes water tangible and people become aware of water (Interview 10, 18); legislation which shows if it is legal to implement a solution (Interview 1); safety (Interview 1); ecological functions (Interview 5); air quality which is important in urban areas (Interview 15); biodiversity (Interview 5, 10, 13); and the environmental footprint of the solution (Interview 15).

Citizens were also asked to address what is important for them when a decision would be made about which stormwater solutions to implement. One of the citizens mentioned that if he would be a decision-maker the first thing to consider is if it makes people life's better and if it takes away the stormwater problems (Interview 8). Another citizen mentioned that it is important if the solution is useful and the way it looks. Where with useful she meant that it has a purpose, such as preventing flooding or that it is good for the plants or the animals (Interview 16). It was also mentioned that it is important to look at how much space is needed for the solution (Interview 4).

4.3 Challenge stormwater management Oslo

During the interviews, several challenges for stormwater management in Oslo came to front. First of all, politicians have besides handling stormwater a lot of other important issues that they need to think about (Interview 21). Therefore, they do not always prioritise stormwater management. In large development projects, many people are involved with different opinions and goals. Landscape architects and water engineers are usually better informed about stormwater problems than other stakeholders. As a consequence, project developers do not see the necessity of stormwater solutions, particularly when solutions are costly or hard to implement (Interview 5).

Too much water is conducted into the pipe system (Interview 5, 19). Stormwater should be treated before it is conducted into the streams (Interview 19). It is hard to find solutions that are easy to implement because there is lack of space (Interview 18, 19). Spatial issues and the usage requirements have to be taken into account when making the transition from underground to open surface solutions. It is not just to lift up what was before underground to the surface. This would be a lost opportunity, because then the social aspects are not included (Interview 10).

Other challenges of stormwater solutions are the feasibility and maintenance (Interview 18). It takes ages to make changes and the process of construction is slow since the building rules are so strict. Certain barriers are the regulation of the territory. When developers want to build new houses, they first need to discuss with the municipality to see how much green there can be in the area. Another problem that was mentioned is that the solutions are often not implemented in a correct way and therefore they do not function effectively. The water is going to wrong places or the solution is not doing what it is meant for (Interview 1). The challenge is to implement the solutions in cities; how to design them and to let them function well (Interview 19).

Another challenge that was mentioned a few times is lack of knowledge (Interview 5, 12, 18, 19). There is good knowledge about how to implement individual solutions (Interview 18) and their effectiveness (Interview 19). However, there is not enough knowledge on how the solutions should be implemented in cities (Interview 19) and how they function under frost conditions, which is often the case in Norway (Interview 5, 12, 21). Furthermore, there is also lack of knowledge on how the solutions function over time (Interview 12), how to integrate different solutions in a system (Interview 18), and how to deal with social problems (Interview 18). Therefore, follow-ups are important to see how the solutions will function in 30 years. Because then it becomes possible to learn from each project, otherwise the errors will be repeated. So, it is important to not just think about the execution but also about the follow-up of stormwater solution (Interview 10).

4.4 Sensitivity analysis

A sensitivity analysis has been done to see if the ranking would be different when using different weights, showing the robustness of the results. For the previous analysis, equal weights are used. However, it is also possible to prioritise a specific criterion by setting a certain parameter at a higher percentage while the remaining weights are equally distributed over the other parameters.

The interviewees were asked to rank the criteria in order of importance. Several experts, mostly engineers, ranked the criterion Effectiveness as most important (Interview 2, 5, 12, 13, 19, 21). However, some of them ranked other criteria as equally important to Effectiveness, such as Side-effects (Interview 5, 12) and Efficiency (Interview 13). Side-effects are also ranked as most or secondly important by several experts (Interview 1, 2, 5, 15, 18, 19, 21). Especially Multiple use and Co-creation were addressed to be important for decision-making on stormwater solutions. The Feasibility of implementation was often ranked as second important (Interview 2, 5, 15, 18) and one time as most important criterion (Interview 1). Those criteria are used for the sensitivity analysis and visible in Table 6. In total, five scenarios are presented. The first four scenarios give priority to a certain criterion while dividing the rest weight over the remaining criteria. For example, when Effectiveness is prioritised with 60%, the other 40% is divided over the rest of the other criteria. Effectiveness is the sum of three sub criteria and has therefore 60% as weight.

Table 6. Sensitivity analysis based on the scores given by experts shown per scenario with priority weighing

Nr.	Stormwater solutions	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
		Effectiveness (60%)	Social (50%)	Multiple use (50%)	Co-creation (50%)	Equal weights
1	Bioswales	3.9 (1)	3.7 (5)	3.9 (4)	3.7 (6)	3.9 (2)
2	Street gutters	2.1 (11)	2.8 (10)	1.7 (10)	1.8 (10)	2.2 (10)
3	Dry detention basins	3.5 (4)	3.7 (6)	3.9 (5)	3.7 (3)	3.6 (5)
4	Reopening parts of streams and rivers	3.8 (2)	4.1 (1)	4.3 (1)	4.0 (1)	3.9 (1)
5	Disconnection of downspouts	3.1 (5)	3.4 (7)	2.8 (9)	3.5 (8)	3.4 (7)
6	Rain barrels	2.8 (9)	3.2 (8)	2.9 (7)	3.7 (5)	3.1 (8)
7	Permeable pavement	3.0 (8)	3.1 (9)	2.8 (8)	2.5 (9)	3.1 (9)
8	Trees	3.1 (5)	3.9 (2)	4.0 (2)	3.7 (4)	3.7 (4)
9	Rain gardens / Rain bed / Planter boxes	3.7 (3)	3.9 (3)	4.0 (3)	3.8 (2)	3.9 (3)
10	Green roofs	3.1 (7)	3.7 (4)	3.7 (6)	3.6 (7)	3.5 (6)
11	Underground solutions such as pipe system	2.2 (10)	2.4 (11)	1.5 (11)	1.5 (11)	1.9 (11)

Table 6 shows that when applying different weights, reopening streams and rivers is still ranked as first, and underground solutions such as pipe systems still as last in most scenarios. This because rivers score high and pipes low on almost each criterion. When Effectiveness is prioritised the ranking is somewhat different, reopening streams and rivers is ranked as second and pipes as tenth. The ranking differs amongst the different priorities, but overall the top ranked solutions are still ranked as high and the low ranked solutions as low.

Looking at the ranking of the interviewed citizens, the Side-effects criterion was several times seen as most important (Interview 9, 14, 16) or secondly important (Interview 4, 7). The sub criteria Multiple use and Nature back to the city were especially mentioned to be important. Some citizens also ranked the Social feasibility of implementation as most or secondly important criterion (Interview 4, 7, 9, 16). Those criteria are therefore used for the sensitivity analysis and visible in Table 7.

Table 7. Sensitivity analysis based on the scores given by interviewed citizens shown per scenario with priority weighing

Nr.	Stormwater solutions	Scenario 1	Scenario 2	Scenario 3	Scenario 4
		Social (50%)	Multiple use (50%)	Nature (50%)	Equal weights
1	Bioswales	4.0 (5)	3.5 (5)	3.8 (5)	3.6 (5)
2	Street gutters	2.7 (9)	1.9 (10)	1.8 (11)	2.1 (10)
3	Dry detention basins	3.2 (7)	2.8 (7)	2.8 (7)	2.8 (7)
4	Reopening parts of streams and rivers	4.4 (3)	4.3 (1)	4.5 (1)	4.3 (1)
5	Disconnection of downspouts	2.7 (9)	2.0 (9)	2.2 (9)	2.4 (9)
6	Rain barrels	2.8 (8)	2.6 (8)	2.3 (8)	2.6 (8)
7	Permeable pavement	3.9 (6)	3.1 (6)	3.1 (6)	3.3 (6)
8	Trees	4.5 (1)	4.1 (2)	4.5 (2)	4.2 (2)
9	Rain gardens / Rain bed / Planter boxes	4.4 (2)	4.0 (4)	4.3 (3)	4.1 (3)
10	Green roofs	4.1 (4)	4.0 (3)	4.2 (4)	4.0 (4)
11	Underground solutions such as pipe system	2.8 (11)	1.8 (11)	1.9 (10)	2.1 (11)

Table 7 shows that solutions with a high ranking are still ranked as high, and solutions with a low ranking are still ranked as low when using different weights. This is the case since those solutions score high or low on most of the criteria. When the Social feasibility of implementation is prioritised, trees are ranked as first. Which means that this solution scores high on this criterion.

Table 8. Sensitivity analysis based on the scores given by citizens questionnaire shown per scenario with priority weighing

Nr.	Stormwater solutions	Scenario 1	Scenario 2	Scenario 3	Scenario 4
		Social (50%)	Multiple use (50%)	Nature (50%)	Equal weights
1	Bioswales	4.0 (5)	3.7 (5)	3.9 (5)	3.7 (5)
2	Street gutters	2.8 (9)	2.3 (9)	2.2 (10)	2.3 (9)
3	Dry detention basins	3.0 (7)	2.9 (7)	2.6 (7)	2.8 (7)
4	Reopening parts of streams and rivers	4.2 (4)	4.2 (2)	4.3 (4)	4.1 (4)
5	Disconnection of downspouts	2.7 (10)	2.3 (10)	2.2 (9)	2.3 (10)
6	Rain barrels	2.9 (8)	2.6 (8)	2.5 (8)	2.6 (8)
7	Permeable pavement	3.3 (6)	2.9 (6)	3.0 (6)	3.0 (6)
8	Trees	4.4 (1)	4.3 (1)	4.5 (1)	4.3 (1)
9	Rain gardens / Rain bed / Planter boxes	4.3 (2)	4.2 (2)	4.3 (3)	4.2 (2)
10	Green roofs	4.3 (3)	4.2 (4)	4.3 (2)	4.2 (3)
11	Underground solutions such as pipe system	2.7 (11)	2.1 (11)	2.1 (11)	2.3 (11)

The sensitivity analysis of the citizens of the questionnaire shows that using different weights does not affect the highest and lowest ranked solutions: namely trees and underground solutions such as pipe systems. However, the ranking of the solutions in between are somewhat different. For example, when Multiple use is prioritised, reopening streams and rivers is ranked as second, while in the other cases this is ranked as fourth. It should be mentioned that the scores of the top ranked solutions do not differ much from each other.

Overall, the ranking of the solutions is not that much different when prioritisation is used compared to equal weights. In some scenarios the ranking is slightly different but this is often because the final scores are close to each other. This analysis shows that the results are not so sensitive for applying different weights and therefore the results are robust.

Chapter 5 Discussion

In this chapter, the case study of Oslo is put in broader perspective, the limitations of the methodology used for this study are discussed and recommendations for decision-makers are given.

5.1 MCDA Framework Oslo in broader perspective

5.1.1 MCDA Framework applicable in other cities

To investigate the perception of experts and citizens of stormwater solutions a Multi-Criteria Decision Analysis Framework was developed. Oslo is used as case study and during the development of the framework certain conditions of the city were taken into account. For example, the effects of frost conditions were considered for the selection of stormwater solutions. However, the selected solutions are also suitable for other cities that do not have to deal with freeze-thaw cycles. But the preference of solutions could differ. For example, in Norway most people do not see the need of using rain barrels because the drinking water is of good quality and water shortages do not occur often. However, in warmer climates water shortage in cities is more common and therefore using rain barrels becomes more interesting.

Some of the criteria have been adapted to the Oslo case. The Effectiveness criterion was divided in three sub criteria based on the three-step strategy of Oslo municipality: reducing the stormwater volume, delaying the runoff and leading the water safely away (Oslo kommune, 2016). Those three steps are also applicable for other cities. However, other municipalities might use different criteria for selecting effective stormwater solutions. For example, how fast the stormwater can infiltrate during heavy rainfall. This criterion might therefore need some adjustment that makes it relevant for the considered city. The Side Effects criterion looks if the solutions contribute to bringing nature back to the city, which also relate to plans of Oslo municipality (Oslo kommune, 2018). In other cities, this might be a less interesting aspect to look at because bringing nature back is not considered to be important. It is therefore recommended to adjust the Side Effects criterion to aspects that are relevant in the specific city. The other criteria, namely the Efficiency, Feasibility of implementation and the remaining sub criteria of Side Effects (Multiple use, Co-creation and Citizenship) are all applicable for analysing stormwater solutions in other cities. In general, the selected criteria would be applicable for analysing the perception of stormwater solutions in other cities.

This framework was developed for analysing stormwater solutions but could also be applied for analysing other climate adaptation solutions. For example, solutions that deal with drought in cities could also be analysed with this framework. The sub-criterion supporting the Water Framework Directive is the only criterion that directly relates to water.

5.1.2 Comparable studies

In order to investigate the perspectives of stakeholders of adaptation options, different methods have been used in European countries. This study used methods such as interviews and questionnaires but workshops and the construction of expert panels can be used as well (European Environment Agency, 2015). The assessment of adaptation options can be executed by experts and nonexperts (Munaretto et al., 2014). Examples are given below.

Expert judgment is often used to assess adaptation options. The Routeplanner (van Ierland et al., 2007) is an example of such study, where experts assessed climate adaptation options in the Netherlands during a workshop. Since this research does not include the judgment of citizens, the selected criteria are more applicable for expert knowledge. For example, for the criterion 'mitigation effect' background knowledge is required. Some of the criteria overlap with the criteria of this study: 'ancillary benefits for other domains' with side effects and 'social complexity' with social feasibility of implementation. Since citizens judgment is included in the study in Oslo, the selected criteria also had to be understandable for them. In order to receive information on criteria that require background knowledge, it was decided to let experts assess the effectiveness of stormwater solution. While this was not asked from citizens.

There are also examples where citizen judgment is investigated. The City of Portland held a campaign to promote green infrastructure in stormwater management, to encourage citizens to learn about stormwater solutions and to be involved in the process. For the research a questionnaire was spread amongst citizens in a neighbourhood about their perception of sustainable stormwater solutions (Shandas, Nelson, Arendes, and Cibor, 2010). It was found that observing the functioning of the stormwater solutions helped in making the people more aware. Furthermore, multiple points of contact and education helped citizens with learning about the stormwater solutions. Increasing the awareness of the participants contributed to some acceptance of stormwater solutions (Church, 2015). The citizens that said to have a high level of knowledge about stormwater management, were more involved in neighbourhood activities (Shandas et al., 2010) . Those results show that there is overlap with the results of this study. For example, raising awareness and creating knowledge is also addressed to be important.

The previous examples look into the perception of experts and citizens separately. However, this can also be investigated at the same time. An example is the study of Apostolaki (2006), that compares the perception of the public and professionals of stormwater management practices in the United Kingdom and Greece. Several results are in line with the findings of this study and are discussed below. The results of the questionnaires and semi-structured interviews showed that the population of cities perceive open watercourses as risk full for children. Also several experts in Oslo experience that citizens consider reopening streams and rivers as a dangerous solution. An important outcome of the study was that “the level of public awareness and the information provided to householders both played an important role in formulating public opinion on stormwater management practices and in generating positive thinking” (Apostolaki, 2006, p.2). Creating public awareness amongst citizens is also addressed to be of importance in this study. In general, the public and professionals preferred more natural systems, which is in line with the preference of green solutions in the Oslo case. However, the opinions were dependent on the site characteristics. The public opinion is highly influenced by aesthetics: when stormwater practices have a high aesthetic value, people perceive the solutions as safer. The design that is used for the solutions is addressed to be important in this study. How professionals value sustainable drainage systems depends on whether the solution is implemented and maintained according to their requirements. The professionals addressed the adoption of maintenance as the most important barrier for the implementation of sustainable stormwater solutions, which is in line with the findings of this study. Professionals addressed that when the solutions “are designed with amenity in mind they become part of the local landscape” (Apostolaki, 2006, p.5). Furthermore, it was addressed that the solutions have potential for positive side effects, such as increasing biodiversity, recreation, high aesthetic areas. Lastly, another similar result is that involving citizens before the implementation of stormwater solutions is important in residential areas. Besides similar results, there are also differences with the study of Apostolaki (2006). It does not use a MCDA and therefore does not give inside on specific criteria.

The above examples show different ways of involving stakeholders in the assessment of climate adaptation options. For this study both expert and citizen judgment is included. In contrast to the comparable studies, this study assesses sustainable stormwater solutions and traditional solutions. This can give insight in different opinions on those two types of solutions. Furthermore, it has the potential to address barriers that can occur when making the transition to sustainable stormwater management.

5.2 Limitations MCDA Framework

The limitations of the used MCDA framework are discussed below. In phase 1, the stormwater solutions were identified. One expert mentioned that solutions should not be separated from their context, as solutions work in combination and support each other (18). This could be investigated in further research.

In phase 2, the criteria were selected. As described in the previous chapter, the importance of maintenance was mentioned several times and could have been emphasised on. Furthermore, some experts pointed out that the feasibility of implementation often depends on whether or not the solution is implemented on public ground. Therefore, more sub criteria could have been used to clarify this distinction. This could have improved the results of this study by getting a clearer understanding of the feasibility of implementation.

In phase 3, experts and citizens scored the selected stormwater solutions. This study makes a distinction between experts and citizens, but it can be argued that experts are also citizens and the other way around. Hence, there could have been a bias in the selection process, since the selected citizens are likely to show a higher interest in the topic and are therefore more willing to participate.

The results might also have been influenced by the language barrier, since the interviewees did not express themselves in their native language. Furthermore, it is important to realise that scoring in MCDA can be subjective (de Bruin et al., 2014) and that the interviewees might have interpreted the criteria differently (Gough and Shackley, 2006).

In phase 4, the final ranking was calculated. As the scores are site dependent it is difficult to generalise.

5.3 Recommendations for decision-makers

Each location and situation are different. Therefore, I recommend flexibility in handling the ranking list presented in the previous chapter. Nevertheless, there are a few points that can be recommended when making decisions on the implementation of stormwater solutions. First of all, a transition is needed from conventional to sustainable ways of handling stormwater. Therefore, decision-makers should realise that the water system should move away from the pipe system to green solutions. Secondly, communication is key. When implementing stormwater solutions it is important to inform and involve relevant stakeholders. When people are involved in the process and understand the necessity and the functioning of stormwater solutions, their awareness level increases and they will most likely be more in favour of the implementation of the solution. For example, the addressed mismatch between experts and citizens about the engagement of citizens in rain barrels and disconnections of downspouts could be solved by good communication. Thirdly, because of the lack of space in urban areas, decision-makers should consider multifunctional stormwater solutions. For example, the space needed for handling stormwater can also be used as parking lot, a playground or as recreational area. Fourthly, it is recommended to look for combination of stormwater solutions. With this, the effectiveness can be increased which makes its implementation more attractive. Fifthly, after the implementation of stormwater solutions it is important to have monitor the effectiveness of the implemented stormwater solutions. This in order to see how the solutions function over time and to decrease lack of knowledge about the solutions.

Chapter 6 Conclusion

This thesis has shown which stormwater solutions are best valued by citizens and experts from Oslo to prepare the city for increasing flood risk due to climate change. The results of this thesis help to understand the perception of citizens and experts, improve the valuation before and after the implementation of the solutions and can be used as input for decision-making on stormwater solutions.

Experts are aware that a transition is needed from conventional to more sustainable water management. Experts and citizens value green solutions more than the traditional or grey solutions. Reopening streams and rivers are ranked as highest by both experts and interviewed citizens while trees are ranked as highest by the citizens of the questionnaire. Underground solutions such as pipe systems scored lowest. However, in contrast to experts, citizens have less opposition against the implementation of pipe systems. An explanation may be that they are less aware of stormwater challenges.

How effective the stormwater solutions are, highly depends on the context, while for efficiency the maintenance and land costs are important. The feasibility of implementing a solution is usually greater when public ground is used. For reopening rivers, planting trees and rain barrels preferences vary widely. There is a strong preference for multifunctional solutions. Furthermore, citizen participation is important because it shows who is going to maintain the solution and it enhances acceptability of the stormwater solutions. Currently, citizens are usually not asked to be involved. Oslo municipality just uses their own knowledge and expertise but citizens could help with thinking about the solutions.

Besides the stormwater solutions scored by the experts and citizens, this study also investigated two socio-economic solutions: public awareness and public financial support. Several interviewees acknowledged the importance of raising awareness about stormwater challenges among the public, developers and urban planners. It helps when people understand the necessity of implementing stormwater solutions. However, there are still a few hurdles to overcome before citizens really get to work. In this case, financial support could help. However, no clear consensus amongst the interviewed experts exists on how effective financial support will be.

For decision-makers it is recommended to investigate in good communication with all stakeholders about the stormwater solutions. To increase the overall effectiveness, it is important to examine the combination of solutions. Furthermore, I recommend that the stormwater is multifunctional, so also can be used for e.g. recreation of parking lot. This promotes the acceptance of citizens of stormwater solutions.

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Figures

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Figure 12: Pervious Pavement. Retrieved on 4-03-2019: https://nacto.org/publication/urban-street-design-guide/street-design-elements/stormwater-management/pervious-pavement/
Figure 13: Parks and open spaces in Oslo. Retrieved on 10-03-2019:
https://en.wikipedia.org/wiki/Parks_and_open_spaces_in_Oslo#/media/File:Colletts_gate.JPG
Figure 13: Wagner, I., & Krauze, K. (2014). How to safely retain stormwater in the city: technical tools. *Sustainable Development Applications*, *5*(January), 72-86.
Figure 14: Managing Stormwater in New England with Low Impact Development. Retrieved on 4-03 2019: https://tataandhoward.com/2015/05/managing-stormwater-in-new-england-with-low-impact-development/
Figure 15: Extensive green roof. Retrieved on 4-03-2019: https://myrooff.com/extensive-green-roof/
Figure 15: Green roof design. Retrieved on 4-03-2019: http://www.markkmorrison.com/greenroof
Figure 16: Burlington's Water Quality Journey. Retrieved on 19-06-2019:
https://www.burlingtonvt.gov/DPW/Water-Quality-History

Appendix

Appendix I. List of papers analysed for selection of criteria

Nr.	Papers
1	Aanderaa, T., & Bothner, N. V. N. (2017). *Før flommen: bærekraftig overvannshåndtering for økt klimaresiliens i norske byer og tettsteder* (Master's thesis, Norwegian University of Life Sciences, Ås).
2	Brouwer, R., & Van Ek, R. (2004). Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands. *Ecological economics*, *50*(1-2), 1-21.
3	de Bruin, K., Dellink, R. B., Ruijs, A., Bolwidt, L., Van Buuren, A., Graveland, J., … Van Ierland, E. C. (2009). Adapting to climate change in the Netherlands: An inventory of climate adaptation options and ranking of alternatives. *Climatic Change*, *95*(1–2), 23–45.
4	de Bruin, K., Kelkar, U., & Mohan, D. (2014). Participatory assessment of adaptation and risk management options for the drought-prone drylands of Jalna District, Maharashtra, India - Final report WP4: Extreme Risks, Vulnerabilities and Community-based Adaptation in India (EVA): A Pilot Study. *TERI Press, New Delhi, India*, 114.
5	Ebi, K. L., & Burton, I. (2008). Identifying practical adaptation options: an approach to address climate change-related health risks. *Environmental Science & Policy*, *11*(4), 359-369.
6	European Communities. (2009). COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC). RIVER BASIN MANAGEMENT IN A CHANGING CLIMATE. *European Commission*, *24*.
7	Gamboa, G. (2006). Social multi-criteria evaluation of different development scenarios of the Aysén region, Chile. *Ecological Economics*, *59*(1), 157–170.
8	Gamboa, G., & Munda, G. (2007). The problem of windfarm location: A social multi-criteria evaluation framework. *Energy policy*, *35*(3), 1564-1583.
9	Garmendia, E., & Gamboa, G. (2012). Weighting social preferences in participatory multi-criteria evaluations: A case study on sustainable natural resource management. *Ecological Economics*, *84*, 110–120.
10	Gough, C., & Shackley, S. (2006). Towards a multi-criteria methodology for assessment of geological carbon storage options. *Climatic Change*, *74*(1–3), 141–174.
11	Haque, A. N., Grafakos, S., & Huijsman, M. (2012). Participatory integrated assessment of flood protection measures for climate adaptation in Dhaka. *Environment and Urbanization*, *24*(1), 197–213.
12	van Ierland, E. C., de Bruin, K., Dellink, R. B., & Ruijs, A. (2007). Routeplanner naar een klimaatbestendig Nederland - a qualitative assessment of climate adaptation option and some estimates of adaptation costs. *Klimaat voor Ruimte.*
13	Martin, C., Ruperd, Y., & Legret, M. (2007). Urban stormwater drainage management: The development of a multicriteria decision aid approach for best management practices. *European Journal of Operational Research*, *181*(1), 338–349.
14	Paneque Salgado, P., Corral Quintana, S., Guimarães Pereira, Â., del Moral Ituarte, L., & Pedregal Mateos, B. (2009). Participative multi-criteria analysis for the evaluation of water governance alternatives. A case in the Costa del Sol (Málaga). *Ecological Economics*, *68*(4), 990–1005.
15	Stagl, S. (2006). Multicriteria evaluation and public participation: the case of UK energy policy. *Land use policy*, *23*(1), 53-62.
16	Weiland, S., Troltzsch, J., Capriolo, A., Den Uyl, R., Jensen, A., Giordana, F., … Russel, D. (2015). *BASE Evaluation Criteria for Climate Adaptation (BECCA)*.

Appendix II. Interview guidelines

1. Interview Guideline Experts

Introductory

1. You can withdraw from this interview at any time without giving a reason.
2. Can I record this interview? I will only use the information for the project itself.
3. What is your profession?
4. What is you experience with stormwater management?

Multi-Criteria Decision Analysis

This section will be supported with a list of pictures with a description of the stormwater solutions, the criteria matrix and the MCDA Framework to score the solutions. Interviewees have to give scores from 1 to 5.

1. **Effectiveness:** Imagine that Oslo has a lot of these solutions …
    a. Reducing stormwater volume: how effective is this type of solution reducing the overall stormwater volume?
    b. Delaying runoff: how effective is this type of solution in delaying the runoff?
    c. Leading the water safely away: how effective is this type of solution in in leading the water safely away?
2. **Efficiency:** Imagine that Oslo has a lot of these solutions …
    a. **Benefits:** how do you judge the benefits for this type of solution when you consider its contribution to solving stormwater problems and other benefits such as recreation, air cleaning, etc.?
    b. **Costs:** how do you judge the costs of the implementation of this solution?
    c. **Cost-benefit ratio:** how do you judge the cost-benefit ratio of this type of solution? (including maintenance costs/long-term benefits)
3. **Feasibility of implementation:** Imagine a neighborhood in Oslo where all the stormwater solutions are proposed to implement, and they are all technically feasible. In this neighborhood the community, municipality and some businesses are involved.
    a. Social feasibility: how do you judge the social feasibility of implementing this solution? Will tenants/municipal agents/developers be supportive or against this type of solution?
4. **Side effects:** How much do you think this type of solution contributes to:
    a. Supporting WFD: meeting the objectives of the WFD?
    b. Oslo green city: making Oslo a green city? Meeting the objectives of 'kommuneplan' of Oslo municipality?
    c. Multiple use (e.g. attractiveness/aesthetic/public health): creating multiple functions for Oslo/neighborhood/own property? Can you explain what the multiple functions are?
    d. Degree of co-creation and citizenship: how high is the potential to involve citizens in the co-creation process of this solution?

Besides technical stormwater solutions, there are also some social solutions that can be considered for implementation.

5. **Public awareness:**
    a. How effective is this solution?
    b. What are the benefits of creating public awareness about stormwater solutions?
    c. In what way can reaching a high public awareness level be achieved?

6. **Public financial support:**
    a. How effective is this solution?
    b. What are the benefits of providing public financial support?
7. Which priority would you give to each criterion, where a higher weight means that it is more important?
    Effectiveness:
    Efficiency:
    Feasibility of implementation:
    Side-effects:
8. Are there any **criteria missing** in this list? What are important criteria when deciding on which stormwater solutions to use?
9. Are there any **stormwater solutions missing** that could be applicable in certain areas of Oslo?

Additional

1. Do you have any suggestions for this study?
2. Do you know any experts/people that you think that could be of value to interview?
3. How can I refer to you? (anonymous / with name / with citation)
4. I will send you a summary of this interview so you can check if you agree with the information.
5. Is it possible to contact you again, once I have gathered more information and new insights?
6. Around June I expect to have completed this study, would you be interested in receiving a copy of the report through email?

2. Interview Guideline Citizens

Introductory

5. You can withdraw from this interview at any time without giving a reason.
6. Can I record this interview? I will only use the information from this interview for the project itself.

General questions stormwater solutions

1. Have your heard of blue-green/stormwater solutions before?
2. Did you experience water-related challenges (e.g. flooding due to heavy rainfall) within the last 5 years? If yes, please specify.

Multi-Criteria Decision Analysis

This section will be supported with a list of pictures with a description of the stormwater solutions, the criteria matrix and the MCDA Framework to score the solutions. Interviewees have to give scores from 1 to 5.

10. **Feasibility of implementation:**
    a. Social feasibility: how happy would you be if this solution is in your neighborhood? When not happy, please explain why?
11. **Side effects:**
    a. Nature back to the city: how much do you think this solution contributes to bringing nature back to the city?
    b. Multiple use: could you imagine that this solution has more functions? How high is the contribution on creating multiple functions?
    c. Co-creation and citizenship: imagine that is has been decided to implement this measure in your neighbourhood, how high is your motivation to be involved in this? In what way?

12. **Efficiency:** Imagine you had this measure in your garden or nearby your house …
    a. Do you think it would change the selling price of your house?
    b. Would you be willing to contribute by either partly paying for it, help with implementation OR maintenance? And yes, in what way?
13. When deciding on the implementation of new stormwater solutions, which criteria are most important to you?
    Feasibility of implementation:
    Side-effects:
    Efficiency:
14. What are important criteria for you when a stormwater measure would be implemented in your neighbourhood? (that are not considered in this study)
15. **Public financial support:** If you would receive some public financial support, how likely is it that you would implement stormwater solutions at your own property?

Personal questions

1. In which area of Oslo do you live?
2. Age range:
3. Level of education:

Additional

7. Do you have any suggestions for this study?
8. Do you know any people that you think that could be of value to interview?
9. How can I refer to you? (anonymous / with name / with citation)
10. I will send you a summary of this interview so you can check if you agree with the information.
11. Is it possible to contact you again, once I have gathered more information and new insights?
12. Around June I expect to have completed this study, would you be interested in receiving a copy of the report through email?

Appendix III. List of interviewees

Nr.	Function	Date	
1	Engineer VAV (Water and Sewage administration)	20-03-19	Expert
2	PhD civil engineer at NTNU	22-03-19	Expert
3	Hydrologist NVE	27-03-19	Expert
4	Student	28-03-19	Citizen
5	Landscape architects Trifolia AS and Asplan Viak AS	28-03-19	Expert
6	Project architect/urban planner	29-03-19	Expert
7	Producer	02-04-19	Citizen
8	Psychiatrist	04-04-19	Citizen
9	Member Pådriv	04-04-19	Citizen
10	Landscape architect AHO	09-04-19	Expert
11	CEO Educational Design Agency	10-04-19	Citizen
12	Geographer PBE	11-04-19	Expert
13	Consultant as water and sewage engineer Asplan Viak AS	12-04-19	Expert
14	Student	12-04-19	Citizen
15	CEO supplier of stormwater solutions	15-04-19	Expert
16	Student	15-04-19	Citizen
17	Landscape architect NMBU	23-04-19	Expert
18	PhD civil engineer at MultiConsult and NTNU	24-04-19	Expert
19	Chief specialist environment and water COWI	29-04-19	Expert
20	Senior engineer PBE	29-04-19	Expert
21	Senior engineer PBE	30-04-19	Expert
22	Retired electrician	03-05-19	Citizen

Appendix IV. Questionnaire

Stormwater solutions questionnaire

Thank you for your interest in filling out this questionnaire. I am Maureen van den Brink, a master student from Wageningen University in the Netherlands. This research is part of the New Water Ways project in collaboration with the Norwegian Institute for Water Research (NIVA) and SoCentral. It looks into stormwater solutions, which are solutions that prepare the city to deal with flooding (e.g. rain gardens or green roofs). The results can help to inform decision-makers about your perception of stormwater solutions and therefore may help in achieving more sustainable water management. No background information is needed, the only requirement is that you live in Oslo.

The survey contains 8 sections and will take approximately 15 minutes to complete.

Your input is highly valuable for this research. The participation is voluntary and you may withdraw at any time. Your answers will be analysed anonymously, and only used in the context of this research. Any personal information will not be shared with other parties.

If you have further questions regarding my research or this questionnaire, you can contact me on maureen.vandenbrink@wur.nl.

Thank you in advance for filling in the online survey.

WAGENINGEN UNIVERSITY & RESEARCH | New Water Ways SUSTAINABLE URBAN WATER MANAGEMENT | SoCentral | NIVA Norwegian Institute for Water Research

General questions stormwater solutions (1/8)

1. **Have your heard of blue-green or stormwater solutions before?**
   - Yes
   - No
   - Not sure
   - Other: ____________

2. **How likely do you think it is that your house/basement will be flooded due to heavy rainfall in the coming 10 years?**

	1	2	3	4	5	
Not likely	○	○	○	○	○	Very likely

3. **How likely do you think it is that flooding due to heavy rainfall will occur in the streets of Oslo in the coming 10 years?**

	1	2	3	4	5	
Not likely	○	○	○	○	○	Very likely

4. **Did you experience water-related challenges (e.g. flooding due to heavy rainfall) within the last 5 years? If yes, please specify.**

Your favourite stormwater solutions (2/8)

In the following section you are asked to score several stormwater solutions.

Different stormwater solutions are presented below. For the questions, you have to imagine that the stormwater solutions are implemented in your neighbourhood.

Explanation stormwater solutions

Stormwater solutions are measures that can be implemented to help the city to deal with rainwater and to reduce flooding during heavy rainfall.

1. Bioswales / 2. Street gutters

1. Open vegetated water systems that handle stormwater. The water flows through a layer of vegetation and infiltrates in the underlying soils. These systems also have the possibility to store snow.

2. Carries water to the next waterbody or to the underground drainage system.

3. Dry detention basins / 4. Reopening streams and rivers

3. Stores water during heavy rainfall, in other times it is dry. Can be vegetated.

4. Currently most waterways are closed inside pipes. However, enclosed rivers have a limited capacity to handle stormwater. By reopening streams and rivers, it becomes possible to better manage water during extreme rainfall.

5. Disconnection of downspouts / 6. Rain barrels

5. By disconnecting the downspouts from the sewage system, you can prevent flooding in the basement in your house or in your neighbourhood. The water will drain into the surrounded garden and lawns.

6. Can be used by households to store rainwater running from the roof and used for gardening.

7. Permeable pavements

7. Water infiltrates through the pavements. Looks like normal pavement.

8. Trees

8. Catch and absorb rainwater, provide shade and increase the biodiversity in the city.

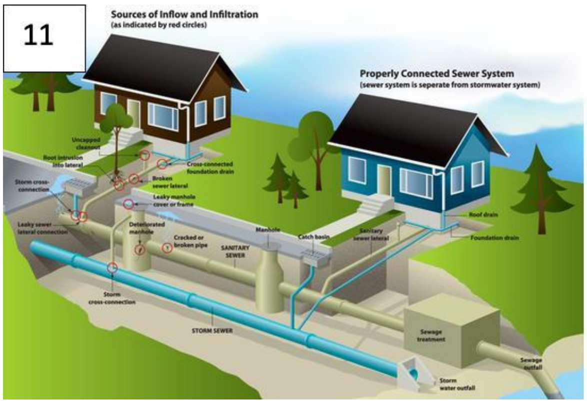
9. Rain gardens/rain bed/planter boxes

9. A vegetated shallow hole allowing stormwater to soak into the ground.

10. Green roofs

10. Vegetation installed on roofs.

11. Underground solutions such as pipe systems



11. Rainwater flows into underground pipeline systems and on to water treatment plants.

5. **Imagine that this solution is in your neighbourhood, how happy would you be about that?**

	Extremely unhappy	Unhappy	No opinion	Happy	Extremely happy
1. Bioswales					
2. Street gutters					
3. Dry detention basins					
4. Reopening streams and rivers					
5. Disconnection of downspouts					
6. Rain barrels					
7. Permeable pavement					
8. Trees					
9. Rain gardens/Rain bed/Planter boxes					
10. Green roofs					
11. Underground solutions such as pipe systems					

6. **When you scored some solutions as (extremely) unhappy, please explain why:**

Oslo as a green city (3/8)

As part of 'the Kommuneplan for Oslo 2018' and in order to prepare the city for climate change, more green areas are planned in the city.

7. **How much do you think this solution contributes to bringing nature back to the city?**

	Measure has no or a very low contribution	Measure has a low contribution	Measure has a medium contribution	Measure has a high contribution	Measure has a very high contribution	No opinion
1. Bioswales						
2. Street gutters						
3. Dry detention basins						
4. Reopening streams and rivers						
5. Disconnection of downspouts						
6. Rain barrels						
7. Permeable pavement						
8. Trees						
9. Rain gardens/Rain bed/Planter boxes						
10. Green roofs						
11. Underground solutions such as pipe systems						

Stormwater solutions with multiple functions (4/8)

8. **Could you imagine that these solutions have more functions besides solving stormwater challenges? (e.g. increasing the attractiveness of the neighbourhood, increasing biodiversity, contributing to aesthetic or social achievements, or contributing to better public health, etc.) Please explain if and how:**

9. **How much do you think this solution contributes to having multiple functions?**

	Measure has no or a very low contribution	Measure has a low contribution	Measure has a medium contribution	Measure has a high contribution	Measure has a very high contribution	No opinion
1. Bioswales						
2. Street gutters						
3. Dry detention basins						
4. Reopening streams and rivers						
5. Disconnection of downspouts						
6. Rain barrels						
7. Permeable pavement						
8. Trees						
9. Rain gardens/Rain bed/Planter boxes						
10. Green roofs						
11. Underground solutions such as pipe systems						

10. **Imagine that is has been decided to implement this measure in your neighbourhood, how high is your motivation to be involved in this (for example with the planning or planting, etc.)?**

	I would have no or a very low motivation to be involved	I would have a low motivation to be involved	I would have a medium motivation to be involved	I would have a high motivation to be involved	I would have a very high motivation to be involved	No opinion
1. Bioswales						
2. Street gutters						
3. Dry detention basins						
4. Reopening streams and rivers						
5. Disconnection of downspouts						
6. Rain barrels						
7. Permeable pavement						
8. Trees						
9. Rain gardens/Rain bed/Planter boxes						
10. Green roofs						
11. Underground solutions such as pipe systems						

11. **If you are motivated to be engaged, how would you like to help? (for example with the design, implementation or maintenance)**

12. **Imagine that you had this solution in your garden or nearby your house, do you think it would change the selling price of your house?**

	Measure has a high negative effect on the housing price	Measure has a negative effect on the housing price	Measure has no effect on the housing price	Measure has a positive effect on the housing price	Measure has a high positive effect on the housing price	No opinion
1. Bioswales						
2. Street gutters						
3. Dry detention basins						
4. Reopening streams and rivers						
5. Disconnection of downspouts						
6. Rain barrels						
7. Permeable pavement						
8. Trees						
9. Rain gardens/Rain bed/Planter boxes						
10. Green roofs						
11. Underground solutions such as pipe systems						

13. **Would you be willing to contribute by either partly paying for the measure, help with implementation or maintenance?**

	I would very much not like to contribute	I would not like to contribute	No opinion	I would like to contribute	I would very much like to contribute
Bioswales	◯	◯	◯	◯	◯
Street gutters	◯	◯	◯	◯	◯
Dry detention basins	◯	◯	◯	◯	◯
Reopening streams and rivers	◯	◯	◯	◯	◯
Disconnection of downspouts	◯	◯	◯	◯	◯
Rain barrels	◯	◯	◯	◯	◯
Permeable pavement	◯	◯	◯	◯	◯
Trees	◯	◯	◯	◯	◯
Rain gardens/Rain bed/Planter boxes	◯	◯	◯	◯	◯
Green roofs	◯	◯	◯	◯	◯
Underground solutions such as pipe systems	◯	◯	◯	◯	◯

Demographics (7/8)

This information will not be shared and is only used in purpose of this research.

14. **What is your gender?**

- ◯ Female
- ◯ Male
- ◯ Other
- ◯ Prefer not to say

15. **Please select your age range:**

- ◯ <18
- ◯ 19-30
- ◯ 31-40
- ◯ 41-50
- ◯ 51-67
- ◯ >67
- ◯ Prefer not to say

16. **What is the highest level of school you are currently in or that you have completed?**

- No schooling completed
- Primary school
- High school
- Applied sciences / University
- PhD / Doctor
- Prefer not to say
- Other: ____________________

17. **In which area of Oslo do you live?**

- Alna
- Bjerke
- Frogner
- Gamle Oslo
- Grorud
- Grünerløkka
- Nordre Aker
- Nordstrand
- Sagene
- St. Hanshaugen
- Stovner
- Søndre Nordstrand
- Ullern
- Vestre Aker
- Østensjø
- Prefer not to say
- Other: ____________________

Other (8/8)

18. **Do you have any remarks or questions regarding this questionnaire?**

____

____

The results of this research will be available on https://newwaterways.no/ in the coming 6 months.

You can find more information about stormwater solutions at 'Overvann' at the website of Oslo Kommune https://www.oslo.kommune.no/vann-og-avlop/skjema-og-veiledere/

Thank you for filling in this survey.

Appendix V. Results Questionnaire