Climate-Smart Stormwater Management (STORMAN)

Summary

Increased precipitation and risk of flooding are major effects due to climate change that Swedish municipalities need to consider, while facing an ongoing growth in population and densification of urban areas. In this context, urban stormwater management represents a growing challenge. The vulnerability of the society towards climate change depends on the capability of the city to responds to environmental issues.

This report presents the challenges and the needs for the implementation of sustainable stormwater solutions encountered in the urban planning process for the city of Gothenburg. The decision making process can be facilitated by the adoption of a stormwater toolbox, which functionalities are designed to support the stakeholders at each step of the planning process. The modules of the toolbox should be designed around a collaboration platform that assists with transparent information flows and allocation of responsibilities. The specific modules (e.g. hydrology, cost-benefit analysis, experience database) should support the needs along the different phases in the process.

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Photograph:

Ulf Bodin, Gothenburg harbor, 2014

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1. Introduction

Rainfall is projected to increase in Nordic countries, especially in the form of extreme events (SMHI, 2017). Together with rising temperature and rising sea level, heavy precipitations are the main consequences of a changing climate, which Nordic cities are not well prepared to manage. According to the Swedish Meteorological and Hydrological Institute (SMHI), by the end of the century the average annual precipitation will be 20-60% greater and the average temperature is expected to be 2-6 °C higher, than for the period 1961-1990. An increase in atmospheric temperature induces also land ice to melt faster than it builds up and causes the sea temperature to rise and increase in volume. Even though in Sweden the sea level is affected by land rise, the sea level has risen at a rate that has nearly doubled in the last 20 years.

What is an extreme rain event?

Heavy or extreme precipitation refers to instances during which the amount of rain or snow significantly exceeds normal levels, for example, in a month or a day or an hour. SMHI's definition of torrential rain is at least 50 mm during an hour or at least 1 mm during one minute. However, extreme conditions depend also on how the precipitation develops over time and how large an area is affected.

An area temporarily covered in water, which is outside its normal confines, is described as flooded (Klimatanpassning.se, 2017). Heavy precipitation and rising sea level increase the risk of flooding, which will become more common especially along the Southern coast of Sweden. The risk of flooding also depends on other factors such as how waterways are regulated, what preventive measures are adopted and how buildings and infrastructure are constructed.

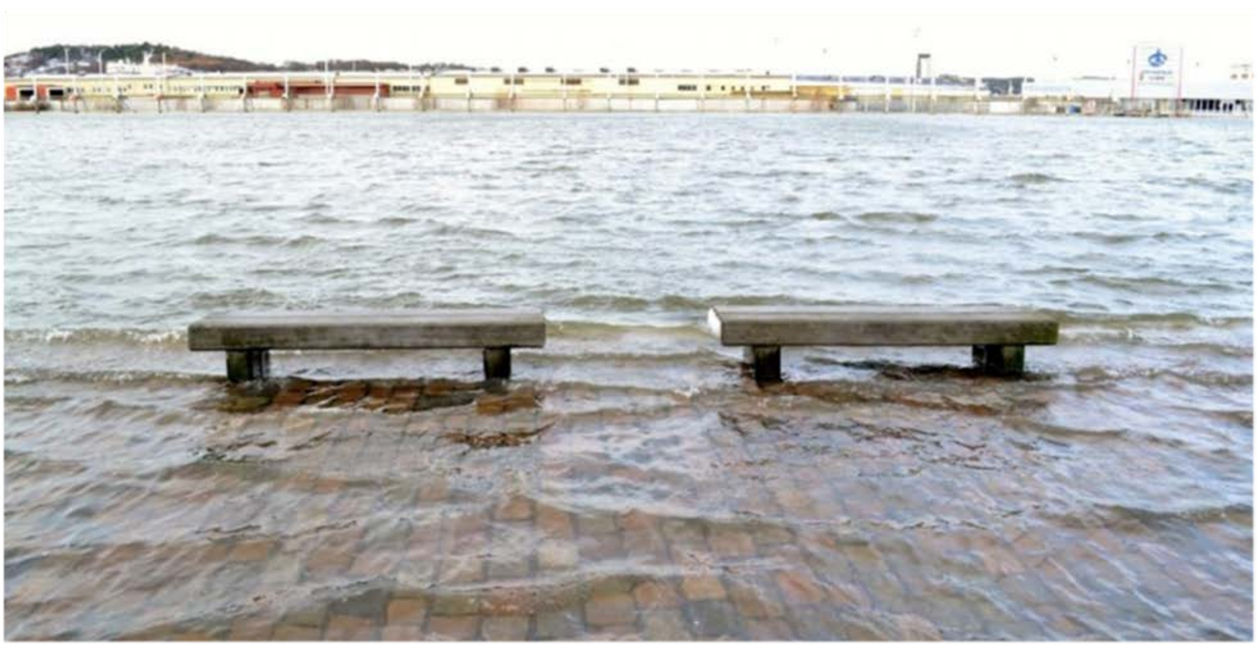

Figure 1: Increased sea level in river Göta älv, behind the Opera House, due to the storm Sven that struck Gothenburg in December 2013. Photo: Susanna Gelin

1.1. Gothenburg

Gothenburg is the second largest city of Sweden and is situated in the catchment area of Göta River. Considering damage on buildings and infrastructure caused by flooding, Gothenburg is the most vulnerable city in Sweden (Moback, 2014). In recent years, the city has experienced several flooding events. In December 2006, heavy rainfall during more than 2 weeks resulted in high river flows, provoking landslide, flooding of many building and the interruption of road and rail traffic (Sörensen and Rana, 2013). Similar flooding repeated in 2013 when the cyclone Sven hit the region, as shown in the Figure 1.

> ***Why are urban areas vulnerable?***
>
> *Urban areas are particularly vulnerable to precipitation, because the rain cannot penetrate into the ground due to the presence of impermeable surfaces, such as roofs and roads, as opposed to natural ground cover that allow infiltration and evapotranspiration. The management of stormwater, which includes rain, snowmelt and the general surface runoff in urban area, is essential to reduce the risk of flooding.*

The traditional approach for stormwater management aims at conveying urban runoff away from the city as quick as possible through channels and pipes. This approach has been shown to cause several environmental problems and to increase the cost of stormwater management (Villarreal-Gonzalez, E. 2005). In Gothenburg, 20% of the city is drained by a combined system which uses a single pipe network to transport both stormwater and sewage to the municipal wastewater treatment plant, while the rest is separate storm water and sewer system (Göteborg Stad 2007). Extreme rain events, which cause overload of the pipe network and the water treatment plant, result in the discharge of untreated sewage into receiving water, causing potential health risks and difficulties to fulfil water quality regulations. Approximately 200 000 m^3 of household sewage are released annually into the river owing to lack of capacity (reference). The municipality is currently reviewing the responsibility for stormwater management in the planning process. Planning and building regulations have until now been unclear, leading to inadequate stormwater management in many new plans and buildings despite recommendations that stormwater should be handled locally.

Proper management of stormwater is necessary not only to reduce the risk of flooding, but also to decrease the amount of untreated pollutants that enter the aquatic environment.

Why is stormwater polluted?

Stormwater often contains pollutants from the surfaces it washes off during a precipitation. Common pollutants are nutrients, heavy metals, pathogenic bacteria, organic compounds and oils. These contaminants originate from for example traffic, sewage systems, atmospheric deposition and oil leakage from vehicles. The pollutants are discharged to the receiving waters along with stormwater. In the receiving waters, the pollutants may cause deterioration of the aquatic environment by exerting toxic effects on plants and animals and contribute to eutrophication.

Stormwater quality improvements are in line with the implementation of the EU Water Framework Directive and its goals as well as several of the Swedish National Environmental Objectives that should be achieve by 2020, including (SwedishEPA, 2012):

- Reduced Climate Impact;
- Natural Acidification Only;
- A Non-Toxic Environment;
- Zero Eutrophication;
- Good-Quality Groundwater;
- A Balanced Marine Environment;
- Thriving Wetlands.

Figure 2: Swedish National Environmental Objectives (SwedishEPA, 201)

1.2. Blue-green solutions

Adaptation efforts can be made to build resilience to extreme precipitation in urban areas. Urban resilience is the ability of adjusting and adapting to internal and external changes (B). Implementing blue-green infrastructure can be a solution to reduce urban vulnerability to heavy precipitation, while delivering multiple benefits, in terms of ecosystem services. Blue-green measures are practices that make use of natural processes to deliver stormwater management services such as retention, infiltration, evaporation, transpiration and slow conveyance in the urban landscape (Fryd, Dam et al. 2012). This approach has been emerging in the last 40 years as opposed to conventional management, which purpose has been to convey stormwater away from the urban settings as fast as possible (Makropoulos, Natsis et al. 2008). Integrating green areas, trees, and waterways is a mean of sustainable stormwater management, since it delivers multiple effects in all the dimensions of sustainable development – ecological, social and economic.

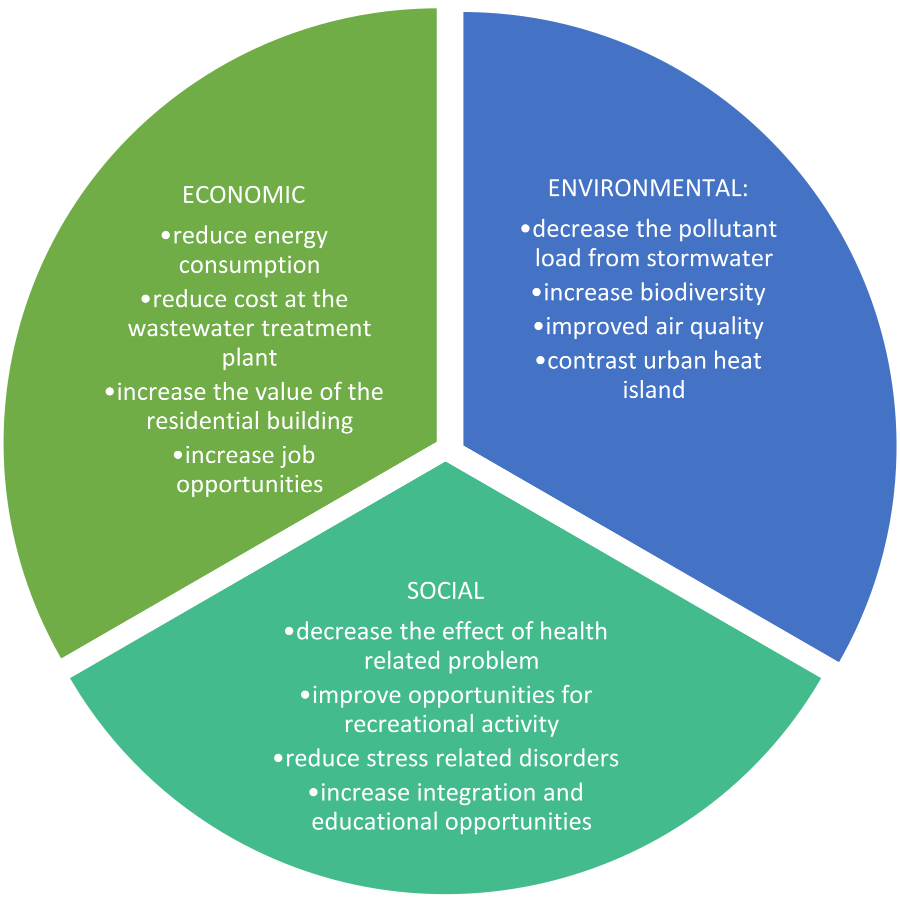

Figure 3: dimensions of sustainable development for blue-green solutions

Different denominations have been created to define these alternative solutions:

- Blue Green Technologies;
- Sustainable Urban Drainage Systems (SUDS);
- Low Impact Development (LID);

- Water Sensitive Urban Design (WSUD);
- Stormwater Best Management Practices (BMP);
- Innovative Stormwater Management (ISM);
- Techniques Alternatives.

In Sweden, the denomination for those practices is Lokalt Omhändertagande av Dagvatten (LOD), which stands for local storm water treatment.

The introduction of sustainability concept in stormwater management requires an integrated approach, which also brings many obstacles under way. It requires measures that agree with spatial planning, traffic, maintenance and management of public areas, urban renewal, etc. in which a large variety of professionals intervene, such as traffic and water engineers, architects, city planners and policy makers. Those interactions are complex by nature, because many actors are involved in the process, a large variety of structures exist and different scale levels and many policy fields are covered (Stahre, P. and Geldof, 2003).

Sustainable stormwater management makes the planning much more complex compared to the planning of traditional stormwater facilities, due to:

- The variety of stakeholders involved. Because the measures are integrated with the urban environment, the planning must be carried out in co-operation with different city departments and actors, with different capacities, knowledge, opinions and working methods;
- The interdisciplinary perspective;
- The sustainability concept involving the environmental (water quality, air quality, water quantity, climate adaptation), social (amenity, education, recreation, economic growth) and economic aspects;
- The technical restrictions (land availability, topography, vulnerable groundwater, etc.);
- The varied spatial and temporal resolutions in which solutions are applied;
- The synthesis of complex, heterogeneous information. The application of sustainable practices within the urban environment is dependent on a number of development-specific characteristics requiring both quantitative and qualitative information to be fully taken into account (Makropoulos, Natsis et al. 2008).

The implementation of blue-green solutions is not a linear process with well-defined statement; rather, it is an iterative loop process of problem solving and problem identification, sustained by constant communication among the different actors involved (Backhaus and Fryd 2012).

1.3. Purpose of the project

The implementation of blue green solutions is not a straightforward process and urban planners need guidance in the evaluation of the most appropriate measures among the many options available to achieve the most cost-effective and practical management strategy possible for the location of interest. Decision supporting tools are necessary to specifically support the selection and evaluation of the right blue green solution or combination of these (Backhaus and Fryd 2012, Lee, Selvakumar et al. 2012).

The STORMAN pathfinder project aimed to assess the need and demand for a decision-making toolbox for stormwater management, with a focus on blue-green infrastructure, as well as defining the functionalities that should be included in the toolbox.

The project had the following specific objectives:

- Understanding stormwater planning and management process in Gothenburg and in Sweden;
- Assessing the challenges and needs in stormwater planning and management to define possible functionalities of a decision-making toolbox;
- Assessing the need and demand for a stormwater toolbox.

The expected results of the toolbox are:

- To provide guidance to urban planners and local stakeholders;
- To improve planning outcomes by providing relevant knowledge;
- To facilitate and accordingly improve participatory planning processes.

The project is limited to the study of Swedish conditions and planning process. The results can vary if considering another European countries due to the large diversity of climatic conditions and regulatory frameworks. In particular, it focuses on the situation in Gothenburg and nearby municipalities.

2. Method

The project was performed in collaboration with the municipality of Gothenburg (Göteborgs Stad) and the enterprise Rent Dagvatten AB. Johanneberg Science Park acted as a facilitator in the organization of the activities and the events.

Current planning, implementation practices and relevant stakeholders in stormwater management in Sweden were investigated through a literature review. The identified stakeholders were invited to a first workshop, where activities were organized with the purpose of assessing the responsibilities, challenges and needs in stormwater planning and management. The papers from the activities of the workshop are collected in the Appendix. Personal interviews were carried out with experts and relevant stakeholders not attending the workshops. No residents, insurance companies and technicians were involved in the investigation; even though they represent important actors, their involvement at this stage of the study was not considered relevant.

Figure 4: stakeholders´ discussion at the first workshop in October 2016

Available decision supporting toolboxes were investigated and their characteristics examined. Based on the results of the activities of the first workshop, a toolbox prototype was created and its functionalities evaluated in a second workshop. The assessment of those functionalities by the participants gave an insight about the structure and the key characteristics of the toolbox.

3. Results

3.1. Available decision supporting toolbox

A decision supporting toolbox is a resource kit that enables the users to improve their knowledge of stormwater management through a set of functionalities. The toolbox has the potential to facilitate the decision-making process, by e.g. identifying preferred drainage control options through the selection and ranking of relevant criteria and indicating the cost and benefits of the selected solutions, also in terms of climate adaptation.

Several toolboxes for water and stormwater management have been developed, but few of them are aligned with a participatory planning process. Some examples are shown in Table 1.

Table 1: example of toolboxes developed for stormwater management

NAME	DESCRIPTION	LINK
THE WEAP SOFTWARE	The WEAP software is a Water Evaluation and Planning Tool to support decisions in the Integrated Water Resources Management. It was initially developed by SEI in 1988 and improved since then continuously. It is freely licensed to all government, research and non-profit organizations in developing countries.	www.weap21.org.
HR WALLINGFORD DRAINAGE TOOLS	HR Wallingford Drainage is a catalogue of different tools, ranging from stormwater storage analysis, site drainage evaluation for best practice compliance, operation and maintenance cost calculator, infiltration design tool, qualitative assessment of the treatment effectiveness of the surface water drainage systems, design evaluation tool, etc.	http://www.uksuds.com/tools.htm
URBAN WATER OPTIONEERING TOOL (UWOT)	UWOT simulates the urban water cycle by modelling usage of water from the household appliance level upwards. In the context of the blue green solutions, it can simulate the effects of techniques on a network of buildings and predict water/energy savings for different future scenarios (e.g. climate change, population growth).	http://bgd.org.uk/tools-models/modelling-and-methodological-tools/
MULTI-HYDRO	It models the urban hydrological cycle, enabling the user to simulate and visualize (in both 2D and stereoscopic 3D) the effects of climate change and extreme weather events, potential urban water management strategies and benefits of blue green solutions.	http://bgd.org.uk/tools-models/modelling-and-methodological-tools/
ADAPTATION SUPPORT TOOL AST	The AST forms part of the Adaptation Support Toolbox, a planning methodology for creating a climate resilient and ecologically sustainable, urban environment. The methodology enables the selection of the optimum combination of blue green solutions, climate change adaptation measures appropriate for the local topography, climate and urban layout and the production of an urban adaptation plan that meets all stakeholders' key needs.	http://www.climateapp.org/
URBAN BEAT MODEL	The Urban Biophysical Environments and Technologies Simulator (UrbanBEATS) is an integrated model for supporting the planning and implementation of Water Sensitive Urban Design (WSUD) infrastructure in urban environments. The model links urban form and water infrastructure planning and assessment in a spatial simulation environment and can be used to engage stakeholders in a collaborative process.	http://urbanbeatsmodel.com/

GREEN INFRASTRUCTURE MODELING TOOLKIT	Developed by USEPA, the models and tools in this toolkit incorporate green infrastructure practices to help communities manage their water resources in a more sustainable way, increasing resilience to future changes, such as climate and extreme events.	https://www.epa.gov/water-research/green-infrastructure-modeling-toolkit
SUSTAIN	A decision support system that assists stormwater management professionals with developing and implementing plans for flow and pollution control measures to protect source waters and meet water quality goals. *SUSTAIN* allows watershed and stormwater practitioners to develop, evaluate, and select optimal best management practice (BMP) combinations at various watershed scales based on cost and effectiveness.	https://www.epa.gov/water-research/system-urban-stormwater-treatment-and-analysis-integration-sustain

The successful implementation of the toolbox depends on its capability to address the right problems. Therefore, the current challenges and needs in stormwater planning were investigated by querying the actors involved in the process.

3.2. Identification of relevant stakeholders

Stakeholders are individuals or entities that have concern in a particular process or decision, either because they are influenced by it or because they can affect the actions, objectives and policies (Loftus, Anton et al. 2011). The main actors involved in the planning and management of stormwater were identified through a literature study.

The stakeholders engaged in the sustainable stormwater planning were divided into four groups of interests: business, municipality, private and academia (Figure 4).

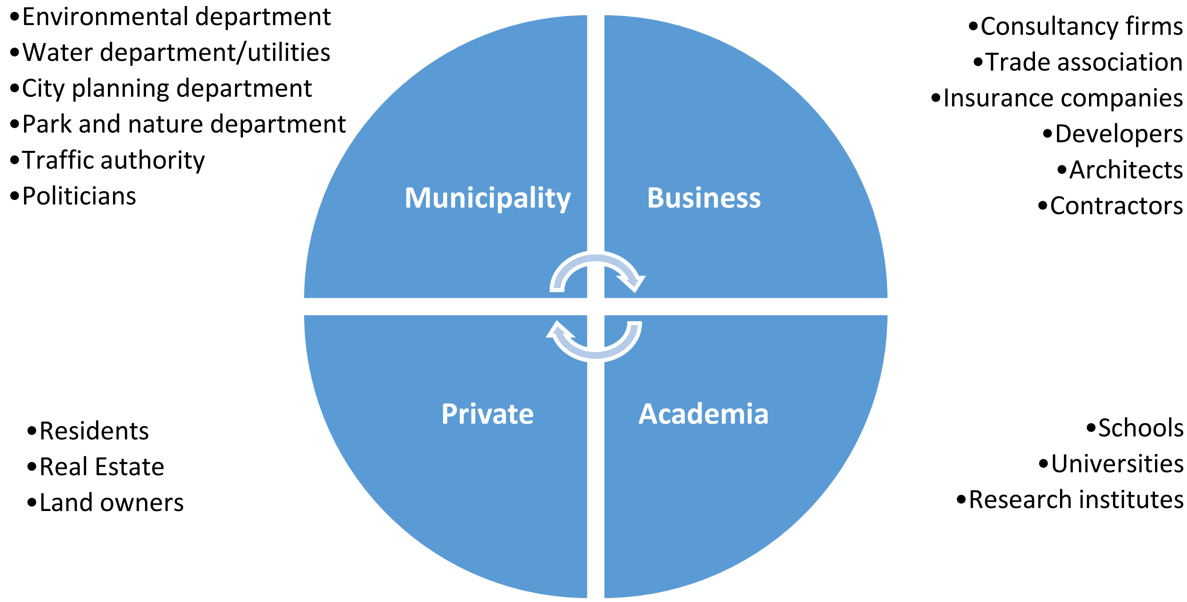

Figure 5: stakeholders of interest in the planning process of sustainable stormwater solutions

The stakeholders involved in the workshops included most of the organizations mentioned above (See Appendix X for the complete list). The activities were attended by 39 and 38 participants, respectively, with a total of 58 individual contributors from the municipalities of Gothenburg, Mölndal, Lerum, Kungälv, Kungsbacka and Öckerö. The main contribution at the workshop was provided by the water and environmental departments and by consultancy companies.

3.3. Stormwater planning and management process

Detailed process maps were developed for each stage of stormwater planning and managements. A schematic representation of the planning process in Gothenburg/Sweden was obtained based on the literature, the workshops and the interviews. Different phases include: comprehensive planning, detailed planning (zoning), design (selection and dimensioning of solutions), construction and operation and maintenance.

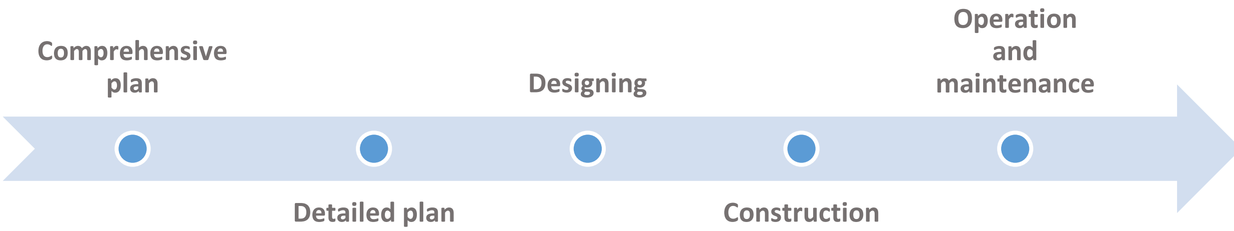

Figure 6: phases in the planning process

The *comprehensive plan*, which embraces the entire municipality, describes the strategies for the urban development. This strategic guide, even though is not legally binding, regulates what is permitted in terms of developments and the zonings should generally comply with the comprehensive plan to be accepted. The *detailed plans* are legally binding and outline the use of land and water areas, as well as what type of buildings may be constructed. The plan consists of regulations, plan maps and a plan description. As an appendix to the zoning documents, it is usually included a stormwater investigation, concerning stormwater management, hydrogeology and environmental impacts. The depth of the investigation significantly varies among the local plans, from just a general recommendation about the use of building material to specific information on site conditions such as surfaces, slopes, soils, groundwater levels and existing stormwater infrastructure. The stormwater investigation may also include suggestions of mitigation measures and facilities. The *designing* step represents a phase when all necessary investigations and projects are carried out to develop a basis for the construction phase, including roads, sewers and specific stormwater solutions. The documentation includes drawings, descriptions, 3D models, etc. After the *construction* step, in which the designed solutions are built, follows the *operation and maintenance* phase.

Stormwater is usually discussed late in the planning and solutions are therefore often not adequately chosen or there is not enough space left to be implemented. While stormwater should be included in all planning stages, local planning is the crucial phase for introducing stormwater in the planning process. Municipalities often have a stormwater handbook, with the purpose of both providing support for people who are planning for stormwater and allocating the responsibilities between the public and private property owners. Local planning is however a complex process including many steps, some of which require the involvement of different actors. Despite the effort made by the municipalities, the distribution of responsibilities for stormwater planning is still unclear and constitutes the major challenge in local planning. Moreover, while stormwater should be introduced as soon as local planning is initiated, it is often introduced much later, making stormwater management difficult.

3.4. Identified challenges in stormwater planning and management

The challenges faced by different stakeholders along the planning process were identified at the first workshop and were grouped in seven categories, illustrated in Figure 6. The greatest challenges are perceived in the comprehensive plan and in the local plan phases, which seem to be the most critical steps in the choice of sustainable stormwater strategies.

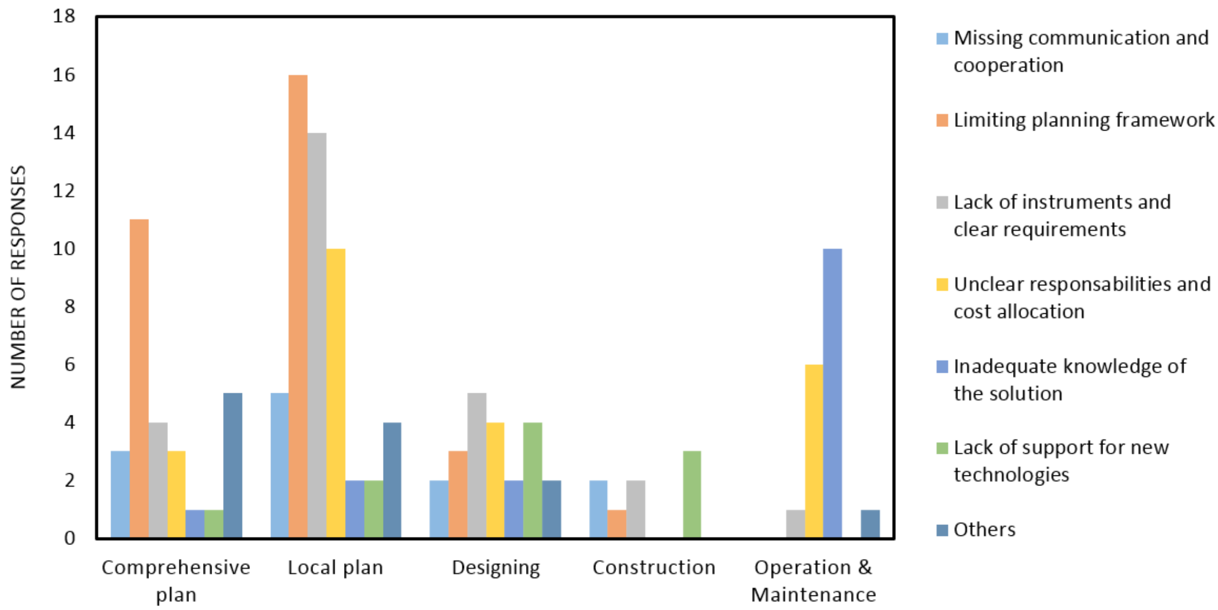

Figure 7: Challenges identified in the planning process

The major challenges include the lack of a clear planning framework and the lack of planning instruments and requirements in the form of strategies and guidelines. The allocation of responsibilities and costs among the stakeholders involved in stormwater management and an inadequate knowledge of the treatment solutions are other relevant obstacles in the implementation of sustainable stormwater measures in the operation and maintenance phase. Some stakeholders experience also missing support in the application of new and innovative technologies, especially in the design and construction steps.

Additional challenges that covered a great share from the participants were grouped under the category "others". This includes the lack of a common political vision which prevents consensus to be reached at the municipal level; the absence of a monitoring and evaluation step of stormwater facilities that are planned but not implemented; a missing stormwater investigation from a larger scale than zoning.

3.5. Identified needs in stormwater planning and management

The needs that were pointed out by the participants reflected the challenge categories. Figure 7 shows the registered number of responses for each category of needs.

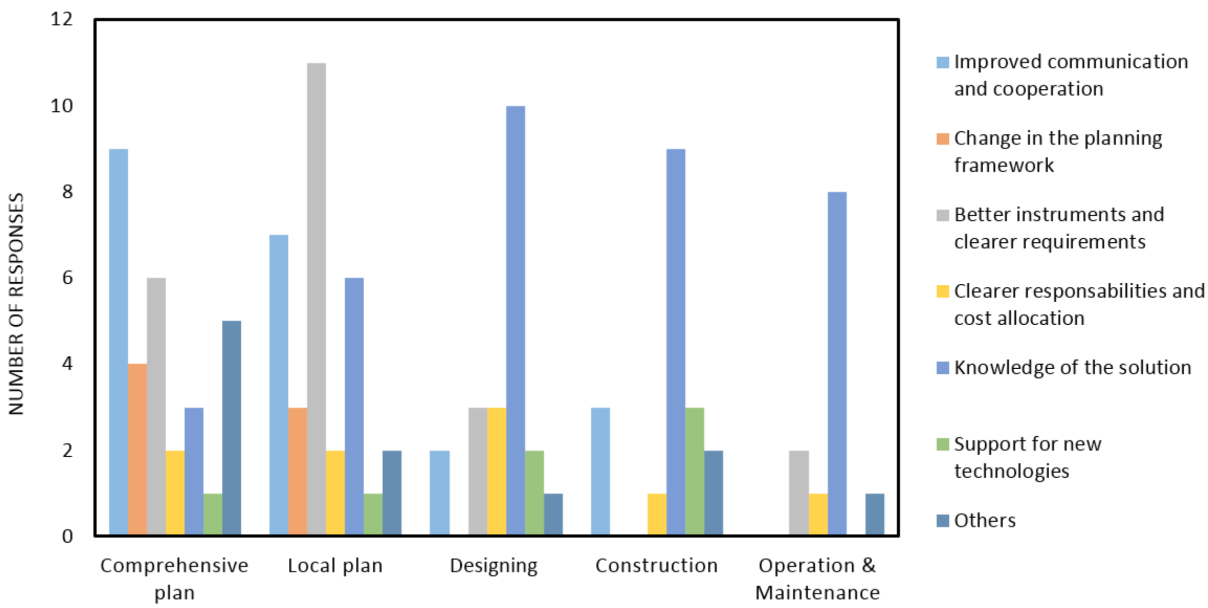

Figure 8: Needs in stormwater planning and management along the planning process

The greatest need seems to be an improved knowledge of the sustainable stormwater solutions throughout the whole planning and management process. Workshop participants also indicated that there is a need for improved communication and cooperation among the stakeholders and for instruments and requirements in the planning phases.

Further actions, grouped under the category "others" include the necessity to reach a common vision and to perceive stormwater as a positive and useful resource, and to monitor the stormwater solutions in an effective and inexpensive way.

3.6. Responsibilities along the planning process

The municipalities have the responsibility to adapt sustainable stormwater management into the urban planning to manage the ongoing densification and new environmental challenges. However, the Swedish legislation does not identify any roles and responsibilities regarding stormwater management for the individual municipal departments. Therefore, the organization looks different for each municipality. Some municipalities have developed a framework for responsibilities for stormwater associated with each department at every step of the planning process (VA SYD, 2008). In the stormwater strategy document for Gothenburg, *"Dagvatten, så här gör vi!"*, some responsibilities are outlined (Göteborgs Stad, 2010). Despite the effort, the departments remain unsure of their respective duties for specific tasks.

During the first workshop, participants were asked to specify their responsibility and related actions along the planning process for stormwater management. The results, which are presented in the Appendix, confirm the high complexity of the planning process and the involvement of many stakeholders with different capacity, perspective and objectives.

The city planning office has the overall responsibility for the comprehensive plan and detailed plan and to contact each department at the early stage of the planning process. Technical stormwater solutions should undergo the responsibility of the water departments and the water utilities. They are also accountable for the economic aspects together with the land owners, the real estate, the park and nature department and the traffic authority. The ecological aspects are evaluated by the environmental department that assumes a monitoring role in the planning process. The park and nature department is also responsible for the social and esthetic features of stormwater solutions and is often in charge of the operation and maintenance.

3.7. Development and assessment of a prototype toolbox

A prototype toolbox was developed in the form of a list of relevant functionalities selected based on the challenges and need. The functionalities include communication functions, information and experience banks, cost-benefit analysis and multi-criteria analysis for decision-making and they are presented in Table 2.

Table 2: potential functionalities of the decision-support toolbox

Toolbox modules	Functionalities
Mapping	A GIS based function, which indicates at a catchment level the location of combined and dedicated sewer system, the current and required stormwater solutions and their connection to the receiving water body
Hydrology	Estimation of water flow and quantity at different output points from a catchment level, including long term projection, consequences of climate change (i.e. rising sea level), groundwater level to prevent subsidence problem. Estimation of risk of flooding in connection with potential retention solutions and infiltration capacity.
Water quality	Estimation of pollution load and discharge of stormwater in the receiving environment; treatment efficiency of stormwater solutions; map of the water quality and sensitivity of the water courses; map of the water quality standards.
Economic Analysis	Cost-benefit analysis, including "soft factors"; cost of the facility considering the added value, the compensatory measures and the payout given by the ecosystem services; operating and maintenance costs; a tool to assess the long-term costs and benefits of conventional and green solutions including sustainability in the total analysis at an early stage.
Added value calculator	Provides information on additional benefits of stormwater solutions (e.g. urban climate) and ecosystem services provided. The module also indicates how stormwater solutions can be coupled with other urban features to maximize the space (e.g. green roofs over bike storage cover; rain gardens at pedestrian areas; swales along bike lanes; etc.).
Multi-criteria calculator	Indication and comparison of the optimal solutions given the site-specific requirements; a digital tool which, given the input of various criteria such as flow, pollution, etc., indicates a portfolio of the potential best solutions.
Communication	A tool that puts people in contact based on the structure of the planning process, responsibilities, skills; it secures an overall assessment by guaranteeing knowledge transfer among the persons involved including the citizens.
Information Bank	A bank that collects all information from the comprehensive plan to the operation and maintenance, including the responsible departments, and makes available to all; examples of information that can be collected are the requirements and conditions proposed in the authorization to stormwater facility, national standards, emission limits, etc. The information bank guarantees the flow of information among stakeholders and provides easy access to it.

Solution bank	A portfolio listing the main stormwater management solutions including pictures, potential suppliers, design standards, required operation and maintenance, volume of treated stormwater, addressed contaminants, technical restrictions, ecosystem benefits etc.
Experience database	A database that provides information, evaluation and feedback on existing stormwater solutions, such as the contact with the suppliers, criteria for designing, cost. The aim of the database is to show bad and good examples, factors leading to success and how to prevent mistakes in the future design.

The functionalities were proposed to stakeholders at the second workshop. The participants pointed out that different stakeholders have different needs at each phase of the stormwater planning and management process. Structuring the toolbox around a communication platform could address the communication needs and improve information flows. A set of tools or functions (e.g. hydrology, cost-benefit analysis, solution bank, etc.) could be available for the different stakeholders to use when relevant. The participants indicated that such a toolbox would be useful for improving stormwater planning and management. Some stakeholders indicated that an experience database would be difficult to keep current and updated, probably because its operability requires human resources and represents a cost. On the other hand, some companies showed their interest to invest money to be part of the solution bank as a mean to advertise their business. That may ensure that the tool lives on incorporating ongoing operations. Several consultants also pointed out that their company already uses internal software that are similar to the toolbox modules and they expressed their concern of losing jobs from their clients if those modules are implemented at a municipal level. The toolbox functionalities should not substitute any existing and well operating software. Open source and commercial hydrology software are already available and widely used; therefore another toolbox with this function is not necessary.

A potential implementation of the toolbox functionalities at the different stages of the planning process is presented below, with the description of the expected results and the problem addressed. Based on our analysis of the first workshop outcomes, the communication function could provide the backbone structure of the toolbox and support information transfer, as well as discussion between relevant stakeholders when decisions involve several stakeholders or municipal departments.

Table 3: implementation of the toolbox modules at different stages of the planning process

	TOOLBOX FUNCTIONALITIES	EXPECTED RESULTS	PROBLEM ADDRESSED
COMPREHENSIVE PLAN	Hydrology Water Quality GIS mapping Information bank	• Stormwater management is evaluated from a broader level, e.g. catchments and sub-catchments. • The hydrology and water quality modules provide an overview of the major risk to consider in terms of pollution and water volume to handle. • The outputs can be presented in a map that shows the goals for each area of the city in order to manage stormwater in a sustainable way • The results can be elaborated and used to write a stormwater policy, with feasible requirements to achieve and easy guidelines to follow. The information bank can collect and provide easy access to those requirements.	The planning framework introduces stormwater management at an early stage. Better instrument and clearer requirements. Holistic view of the problem facilitates the achievement of consensus.
DETAILED PLAN	Multi-criteria calculator Economic analysis Information bank	• The local conditions need to be integrated with the general requirements and guidelines of the catchment areas. The multi-criteria calculator can address the specific technical restrictions, while providing a basis for agreement, covering the different interests of all the stakeholders. • Once the functional requirements for stormwater management are agreed, the Economic Analysis gives an economic perspective for the decision and facilitate the division of cost and responsibilities including also operation and maintenance. • The information bank registers the responsible stakeholders for the cost of the solutions and the operation.	The requirements for an effective management are defined and easy to access. The management of stormwater reflects the needs from a local and catchment level. Clear responsibilities and cost allocation.
DESIGNING	Solution bank Experience database Added value calculator Information bank	• The added value calculator provides information on how stormwater can be used as a positive resource that enriches the environment. • The solution bank and the experience database provide knowledge support. • The information bank registers the purpose of the stormwater solution as well as the implementation agreements.	Clear responsibilities and cost allocation Stormwater perceived as a positive resource Knowledge of the solutions and support for new technologies are provided

CONSTRUCTION	Solution bank Experience database Information bank	• The solution bank and the experience database can serve as a knowledge support for the construction of the solutions and can provide the link between the providers and the constructors. • The constructed solution can enter the experience database in which the operating instructions are carefully described.	Knowledge of the solutions and support for new technologies are provided
OPERATION & MAINTENANCE	Information bank Experience database	• The information bank provides reference contact information. • The experience database registers the feedbacks of the operators regarding the solutions.	Knowledge of the solutions and support for new technologies are provided

4. Discussion and future development

The toolbox and the arrangement of its functionalities represent one of the potential ways to improve stormwater management in a Swedish municipality. The basis for the study was provided by the local conditions and planning framework of Gothenburg. The scale of the city should also be taken into account when stormwater management is discussed, since it may be straightforward in smaller municipalities where the responsibilities are limited to fewer stakeholders. Moreover, the outcomes of the project are influenced by the vision of the participants of the workshop. For example, the fact that more challenges are located in the planning phase may be the results of the contribution of stakeholders involved in the first stages of the planning process. The toolbox and its modules is intended to provide decision support and promote a more structured process of stormwater planning including management of climate change consequences. A more structure process is also needed to facilitate follow-up of the function and operation of management solutions. Currently, a monitoring step to guarantee the proper implementation and control of the measures indicated in the detailed plans is lacking.

The current planning framework, which does not account for stormwater management early enough in the process, limits the feasibility of stormwater treatment measures, in particular those that require space to be implemented and are competing with other structures in an urban environment that goes towards densification. A review of planning and management functions in the municipality is required also to improve communication among the different departments to build a consensus around climate change and a common vision for stormwater management. Many actions could also benefit from collaboration with other Swedish municipalities. A climate adaptation index could be a tool that helps cities benchmark their performance and serve as a basis for the comparison of different water management choice and identification of the best practices in the field of stormwater among the Swedish and European cities. The proportion of separated and combined sewage system or the percentage of green area within a municipality could be examples of potential key indicators to recognize the stormwater-resilient cities.

The lack of clear instruments and requirements may be a consequence of the fact that there is no formal definition of stormwater in Swedish jurisdiction and the management is not defined. According to the Swedish Environmental Code (Miljöbalken), stormwater is still considered as wastewater. The lack of clarity and consistency may lead to misperception, poor planning and reduced investment (Alm & Åström, 2014).

5. Conclusion

The urban stormwater planning process involves many stakeholders. Efficient communication is therefore key to successful planning and implementation of stormwater management. Communication should be initiated early in the planning process and stakeholders should be included at different stages with an efficient flow of information. An early introduction of stormwater issues in the planning framework and a better support in form of guidelines and strategies should lead to a more efficient implementation of sustainable stormwater management.

Nordic cities are not well prepared for the projected increase in precipitation resulting from climate change. As cities need to improve stormwater planning and management, the proposed toolbox can support the decision-making process, while preserving the multi-objectivity nature of the problem. The toolbox should be designed around a communication platform to improve decision-making and information flows. Specific tools and functions (e.g. hydrology, cost-benefit analysis, experience database) should support different phases in the process. Based on stakeholder input, a toolbox is needed in a Nordic context. Further investigation of stormwater planning in other European countries is currently performed to assess the need for such a toolbox in other European countries.

6. References

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Appendix

A: activities from the first workshop

The identified stakeholders were invited to a first workshop, where activities were organized with the purpose of assessing the responsibilities, challenges and needs in stormwater planning and management. The participants were divided in groups with a diversity of stakeholders and were given the following questions to reflect upon.

Indicate for each step of the planning process (i.e.: comprehensive plan, detailed plan, designing, construction, operation and maintenance):

- *Your responsibility and role; what kind of decision do you take in the different stages of the decision making process? What are the expected results of your decisions?*
- *The challenges and the obstacles you face; at which phases of the planning process, should you be involved, when you are usually not engaged?*
- *Your needs; what kind of information and support do you need? What input do you need to make decisions?*

The answers were placed with post-it on A0 papers illustrating the planning process.

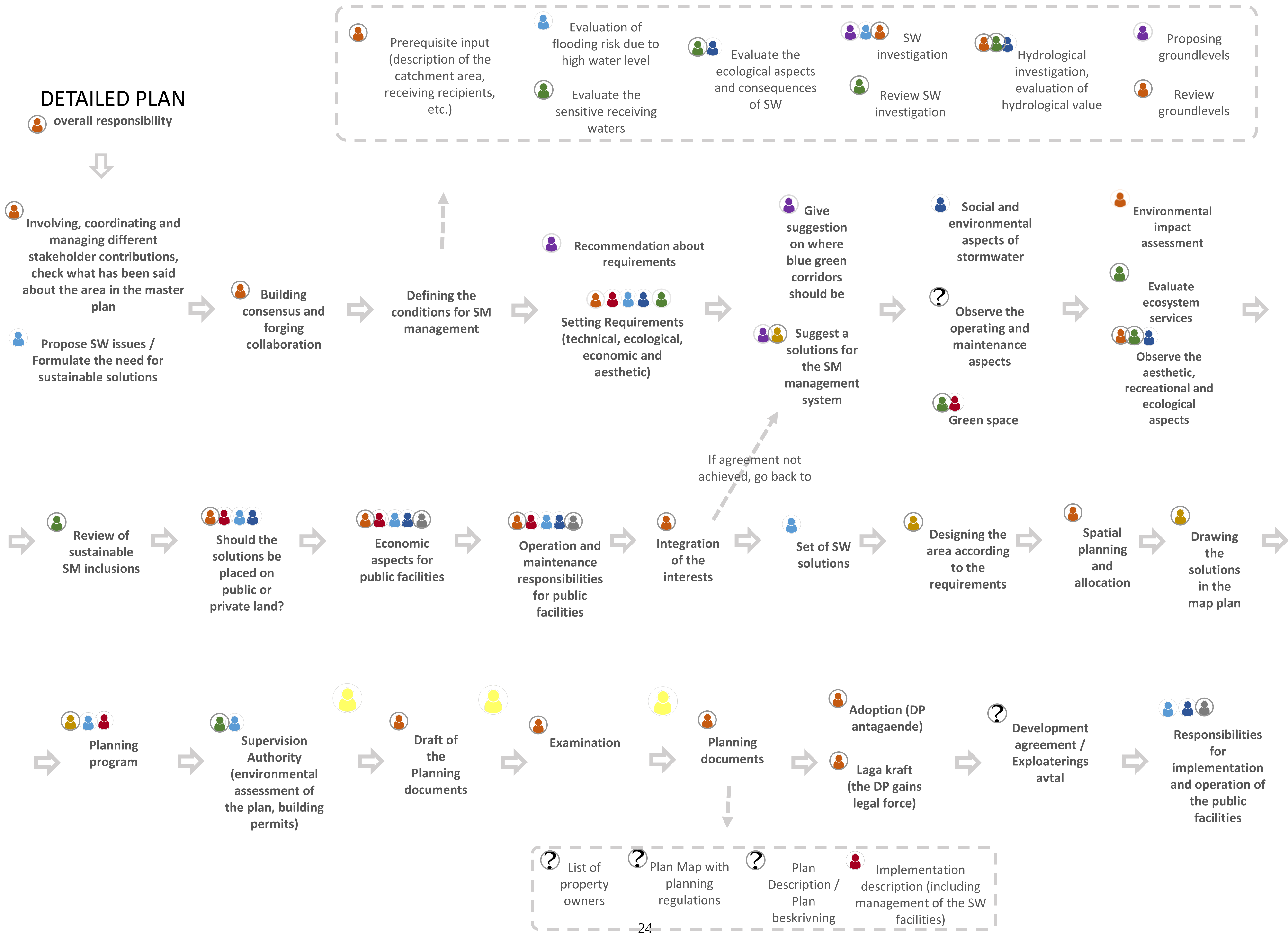
B: activities from the second workshop

The second workshop focused around the communication among the different actors and the functionalities of the toolbox. The participants were requested to define the type of stakeholder in which they identify and discuss whether the communication with the other stakeholders along the planning process is effective or not. The participants were also asked to comment on what they would like to change in this communication (whether there is a need for better communication, lack of money, time or other resources, etc.). In the second activities, the stakeholders were asked to debate around the different possible functionalities of the toolbox (see Table 2), whether the modules could help in the decision-making process and which kind of output would improve it.

C: responsibilities along the planning process

The decision-making process for stormwater (here abbreviated to SW) planning involves a multitude of different stakeholders with different responsibilities at each phase. Understanding the flow of information and the roles is a challenging task. Based on the results of the first workshop, a flowchart representing how the detailed plan process would flow was created for each step of the planning process. The arrows indicate a probable order of the actions, while the different colors represent the stakeholders involved in the decision (Figure 9). The dashed line represent sub-categories of a specific step.

Figure 9: corresponding colors for the stakeholders


DETAILED PLAN
overall responsibility
Prerequisite input (description of the catchment area, receiving recipients, etc.)
Evaluation of flooding risk due to high water level
Evaluate the sensitive receiving waters
Evaluate the ecological aspects and consequences of SW
SW investigation
Review SW investigation
Hydrological investigation, evaluation of hydrological value
Proposing groundlevels
Review groundlevels
Involving, coordinating and managing different stakeholder contributions, check what has been said about the area in the master plan
Propose SW issues / Formulate the need for sustainable solutions
Building consensus and forging collaboration
Defining the conditions for SM management
Recommendation about requirements
Setting Requirements (technical, ecological, economic and aesthetic)
Give suggestion on where blue green corridors should be
Suggest a solutions for the SM management system
Social and environmental aspects of stormwater
Observe the operating and maintenance aspects
Green space
Environmental impact assessment
Evaluate ecosystem services
Observe the aesthetic, recreational and ecological aspects
If agreement not achieved, go back to
Review of sustainable SM inclusions
Should the solutions be placed on public or private land?
Economic aspects for public facilities
Operation and maintenance responsibilities for public facilities
Integration of the interests
Set of SW solutions
Designing the area according to the requirements
Spatial planning and allocation
Drawing the solutions in the map plan
Planning program
Supervision Authority (environmental assessment of the plan, building permits)
Draft of the Planning documents
Examination
Planning documents
Adoption (DP antagaende)
Laga kraft (the DP gains legal force)
Development agreement / Exploaterings avtal
Responsibilities for implementation and operation of the public facilities
List of property owners
Plan Map with planning regulations
Plan Description / Plan beskrivning
Implementation description (including management of the SW facilities)