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Master Thesis

Water Sensitive Urban Design (WSUD) as a climate adaptation strategy

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Abstract

"Global floods and extreme rainfall events have surged by more than 50% in the past decade and recent studies show that they are occurring four times higher than in 1980" (Neslen, 2018). At the same time, the urban population is rising. Today, 55% of the world's population lives in urban areas and it is estimated to increase to 70% by 2050 (United Nations, 2018).

This expansion of urbanized areas is correlated with the increase of impermeable surfaces that, in case of extreme weather events, are not able to drain the water efficiently. The rainfall-runoff is channelled from roads, parking lots, buildings, and other impervious surfaces to storm drains and sewers that cannot handle the volume. The high ratio of impermeable surfaces and the increased extreme rainfall events cause severe environmental, social, economical problems in urban areas. Merely technical and engineering solutions are no sufficient, therefore a new approach that can maintain and adapt the natural water cycle inside the urban areas is needed. Ecosystem services and resilience thinking have become key principles in adaptation strategies at different levels, from international policies (e.g. Sustainable Development Goals) to local actions (e.g. Copenhagen adaptation plan 2015) and design (e.g. climate resilient San Kjeld in Copenhagen).

In this scenario, the design approach of Water Sensitive Urban Design (WSUD) aims to promote resilience at the local level by managing stormwater, encouraging the defence of the aesthetic value of green and blue areas. WSUD is a multidisciplinary approach that involves water management, urban planning, architecture, and landscape design. The main idea of WSUD is that sustainable stormwater systems should be beautiful, meaningful, and educational (Echols, 2007).

This master thesis explores the concept of Water Sensitive Urban Design and its application in the cities of Copenhagen, Malmö and Rotterdam. The case study of PHVision in Heidelberg, Germany, is analysed from the concept of WSUD. Design improvements are suggested stemming from the analysed European examples and the theoretical background.

Keywords:
Water Sensitive Urban Design, Flooding, Resilience, Climate adaptation, Rotterdam, Copenhagen, Malmö, PHVision

A livello mondiale il verificarsi di inondazioni e di intensi temporali sta avendo un incremento superiore del 50% rispetto ai decenni passati e recenti studi dimostrano che questi fenomeni si stanno verificando quattro volte più intensamente rispetto al 1980 (Neslen, 2018). Allo stesso tempo la popolazione urbana sta aumentando. Attualmente, il 55% della popolazione mondiale vive in aree urbane e si stima che questa percentuale aumenterà fino ad arrivare al 70% nel 2050 (United Nations, 2018).

Questa espansione delle aree urbanizzate è correlata ad un aumento delle superfici impermeabili che, in caso di eventi metereologici estremi, non sono in grado di drenare l'acqua piovana in maniera efficiente. Il deflusso della pioggia è canalizzato da strade, parcheggi, edifici e altre superfici impermeabili nel sistema fognario che non è in grado di gestire questi intensi volumi d'acqua. L'elevata quantità di superfici impermeabili e l'incremento degli eventi meteorici estremi sta causando molti problemi, nelle aree urbane, a livello ambientale, sociale ed economico. Le sole soluzioni tecniche ed ingegneristiche non sono sufficienti, pertanto è necessario un nuovo approccio in grado di mantenere e adattare il ciclo naturale dell'acqua all'interno delle aree urbane. I servizi ecosistemici e il concetto di resilienza sono diventati principi chiave nelle strategie di adattamento a diversi livelli, dalle politiche internazionali (ad es. Obiettivi di sviluppo sostenibile) alle azioni locali (ad es. il Piano di adattamento di Copenaghen 2015) e al design (ad es. il quartiere resiliente di San Kjeld a Copenaghen).

In questo scenario, l'approccio progettuale del Water Sensitive Urban Design (WSUD) mira a promuovere la resilienza a livello locale gestendo le acque piovane ed incoraggiando la difesa del valore estetico delle aree verdi e blu. Il WSUD è un approccio multidisciplinare che coinvolge la gestione delle risorse idriche, l'urbanistica, l'architettura e la progettazione del paesaggio. L'idea principale del WSUD è che i sistemi sostenibili di gestione delle acque piovane dovrebbero essere esteticamente belli, ma avere anche un valore educativo (Echols, 2007).

Questa tesi di laurea esplora il concetto di Water Sensitive Urban Design e la sua applicazione nelle città di Copenaghen, Malmö e Rotterdam. Successivamente, il caso studio di PHVision ad Heidelberg, in Germania, viene analizzato secondo il concetto del WSUD. Vengono quindi suggeriti dei miglioramenti per il progetto derivanti dall'esame degli esempi europei e dalle analisi condotte a livello teorico.

Preface

This final degree project represents the end of my master Double Degree experience in “Territorial, urban, environmental and landscape planning” at Politecnico di Torino (Italy) and in “Sustainable Urban Planning and Design” at KTH in Stockholm (Sweden). This final dissertation is a research document in which I combine the theoretical knowledge assimilated in Turin and Stockholm, with the skills acquired during my internship in Ramboll Studio Dreiseitl (Überlingen, Germany). This internship was a bridge experience between the university and the future working life.

At the end of this master project, I would like to say a big thank you to my supervisors in KTH and Politecnico, Elisabetta Troglio and Ombretta Caldarice, for their continuous support as well as for the valuable comments over the whole process.

Great thanks to my boss Gerhard Hauber for the opportunity that he gave me to work in Studio Dreiseitl, and to all my colleagues, especially Luca Della Torre, Ran Ding, and my team leader Tobias Baur.

I would also like to say a big thank you to my family and my Italian friends who supported me during these years in the university, but also to the friends that I met in Stockholm and made the year in Sweden an amazing experience.

Finally, a special thank you to my cousin Anna, my classmates in Politecnico Chiara and Davide, and to my friend Bentley who supported me during the thesis development.

Questa tesi rappresenta il termine del progetto di doppia laurea in “Pianificazione territoriale, urbanistica e paesaggistico-ambientale” presso il Politecnico di Torino (Italia) e in “Sultaniale Urban Planning and Design” preso il KTH di Stoccolma (Svezia). Questo documento di ricerca riunisce le conoscenze teoriche assimilate a Torino e Stoccolma con le competenze acquisite durante il tirocinio presso Ramboll Studio Dreiseitl (Überlingen, Germania), un’esperienza ponte tra l’università e la mia futura vita lavorativa.

Al termine di questa esperienza vorrei ringraziare sinceramente le mie relatrici Elisabetta Troglio e Ombretta Caldarice per il loro continuo supporto e per i loro preziosi commenti forniti durante l’intero percorso.

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Vorrei inoltre ringraziare la mia famiglia, i miei amici italiani che mi hanno supportato durante tutti questi anni di università e gli amici che ho conosciuto a Stoccolma i quali hanno reso il mio anno di studi in Svezia un’esperienza indimenticabile.

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Introduction

I. Aim of the research

The research is focused on the concept of Water Sensitive Urban Design (WSUD), a new water management approach that is still not commonly used.
The research aim is to analyze how WSUD is changing the way of managing rain in cities by using the water as a design element. In order to do that, some reference projects are studied: Augustenbirg in Malmö, Zomerhofkwartier (ZoHo) in Rotterdam, and San Kjeld in Copenhagen. The analysis, based on a predefined set of criteria, provides some learning outcomes for the integration of WSUD solutions on the case study of PHVision, Heidelberg - Germany.
Since PHVision is still in a design phase, a secondary aim of the research is to use the learning outcomes of the European examples for providing possible suggestions and promote debate on how to support planners and decision-makers in the following planning phases.

II. Research Questions

The overarching research question that this master thesis aims to explore is:

How does Water Sensitive Urban Design change the integration of water in urban planning from waste to design element?

To properly address this question, the master thesis is organized by some sub-questions. The first is related to the examples in Europe and is:

Considering the design, planning, and public participation aspects, what can be learned from relevant European examples that have implemented WSUD?

The final sub-question is related to the case study of PHVision in Heidelberg:

Are there some suggestions that are possible to implement in PHVision based on the experiences of the selected European examples and the implementation of WSUD?

III. Methodology of the study

To explore the research question and the sub-questions, the project has been conducted by a triangulation of methods including a literature review of the current water management system history and the explanation of the WSUD concept. A literature review can be described as a systematic way of collecting and synthesizing previous research (Baumeister & Leary, 1997; Tranfield, Denyer, & Smart, 2003). A well-conducted literature review creates a firm foundation for advancing knowledge (Webster & Watson, 2002) and the integration of different findings can address in a good way the research questions (Snyder, 2019).
After the literature review, a desk review of a set of reports was done. Desk research is basically involved in collecting data from existing resources and it can be internal (the information are collected inside the organization) and external (the information are collected outside the organizational boundaries) (Hague & Wilcock, 2020). In order to find the criteria for the European examples analysis, external desk research was done, while the information regarding the case study of PHVision were collected through internal desk research using the documents developed by the studio where I performed my internship.
In particular to answer at the first sub-question "Considering the design, planning, and public participation aspects, what can be learned from relevant European examples that have implemented

WSUD?” were used the criteria developed by the Hafencity University within the scope of the project SWITCH. SWITCH is a European project that involved innovation in the area of sustainable urban water management over the period 2006 to 2011. These criteria permit a qualitative explanation of how the chosen examples developed the WSUD. Papers, planning document, and the official websites of the studios and international firms that developed the projects were used to find the information necessary to fill in every analysis criterion and develop a complete overview of the three projects.
The explanation of the case study of PHVision was permitted using the documents made by the studios that are developing the project. Case study is an ideal methodology when a holistic, in-depth investigation is needed (Feagin, Orum, & Sjoberg, 1991). For the research, the case study of PHVision was useful to understand how to overcome the idea of rainwater as a waste and answer to the research question. These papers made by the studios that is developing the project are a valuable source of analysis and information realized through on-site surveys and workshops made in collaboration with all the stakeholders involved in the project. Gaining advantage from my internship in Ramboll Studio Dreiseitl (one of the international firms that developed the PHVision project), I could collect firsthand data by working directly on the development of the project. The information were also collected using informal discussion that happened during the meetings or through informal chats during the development of the project. An informal discussion is a not structured interview that takes place in a casual setting, such as over coffee or lunch (Kirkman, 2006). In these occasions the project developers where informed that the materials collected would have been used for the master thesis research. Using these data, it was possible to develop a layer analysis to understand better the structure and the functioning of the new district. For a better understanding of the projects, also maps and sections were used. Part of this graphic material has the copyright of Ramboll Studio Dreiseitl since it was developed during my internship experience in the studio. The remaining material was personally developed for this research using the same graphic style because I was one of the team components that developed the PHVision in Ramboll Studio Dreiseitl so I know how the project was drawn.
The possibility to perform an internship in one of the studios that developed the case study of this research was for sure an essential strength. I had the possibility to have informal discussions with the project’s developers and to get access to the database where all the information are stored. On the other hand, I did not have the same opportunity for the European examples, and this was for sure a weakness. Talking directly with the local administrators and with the planners who carried out the projects would have allowed me to have more detailed information. In any case, the chosen projects are considered best practices in Europe for the implementation of WSUD. For this reason, through extensive internet research, it was possible to find enough material to answer the research question in an exhaustive way.

IV. Delimitations of the study

The master thesis focuses on water management using the Water Sensitive Urban Design approach. In light of this, the study only considers flooding events related to climate change without consider another main problem which are the heat waves.
The heat waves has severe impacts especially in urban areas. The WSUD approach is also useful to balance heat waves thanks to the thermal regulation capacity of water elements but, since a deeper analysis is necessary to have a complete overview of the whole benefits related to WSUD, it is not possible to discuss it within this thesis .
Another delimitation is that the analysis did not consider the economic aspects. Understand the quantity of money necessary for the development of the project is fundamental in order to understand

if a project can be implemented or not. Despite this, deeper analyses are needed, and the economic aspects are something that it is not possible to discuss within this thesis.

V. Structure of the study

The master thesis is structured as follows.
In **CHAPTER 1**, research regarding the topic of water management in cities and the concept of Water Sensitive Urban Design is presented. The last part of the chapter focuses the attention on the progress of WSUD in Germany, where the case study is located. A specific focus on German laws in terms of urban water drainage demonstrates the importance of this notion in the planning system. Finally, some criteria for the projects' analysis are shown.

CHAPTER 2 focuses on the three selected European reference projects; the district of Augustenborg in Malmö, the Zomerhofkwartier (ZoHo) in Rotterdam, and the San Kjeld district in Copenhagen. Augustenborg is chosen since it is one of the first European projects that implemented WSUD in Europe and it represents a forerunner for the implementation of this concept in other European cities. The WSUD is mainly implemented in the green areas and can represent a valuable best practice for the case study of PHVision. Rotterdam and Copenhagen have been chosen because, unlike Augustenborg, in these two cities WSUD is applied in a dense urban structure with similar characteristics to the case study of PHVision. In particular, Rotterdam is interesting in the innovative solution implemented and Copenhagen for the capacity that the city has to redevelop the whole public spaces.
This chapter focuses on the background analysis of the sites, considering the situation before the project and the reason(s) that promoted a redevelopment by using WSUD. The second part is an overview on the WSUD tools implemented in the project. The third part consist in the criteria' application and in the end, some finally outcomes are identified to answer at the first research sub-question.

CHAPTER 3 is related to the PHVision case study. Firstly, a historical analysis of the area is given as background introduction. After, an explanation of the Internationale Bauausstellung (IBA) planning tool, which began the planning and process in the study area, is provided. In the third section related to PHVision, the redevelopment process at the Heidelberg project site is presented. In the last part there is a discussion on how the projects could overcome the problems of the current water management systems identified in chapter 1. Finally, some suggestions for the projects are developed. These suggestions are based on the learning outcomes identified in chapter 2 and based on the analysis of the European projects.

CHAPTER 4 the final discussion focuses the attention on the master thesis research question "How does Water Sensitive Urban Design change the integration of water in urban planning from waste to design element?" The question is answered by considering the results of the project analysis in chapters 2 and 3 and considering how they respond to the goal of WSUD explained in the theoretical part.

Chapter 1

Background and literature review

1.1 The clean water relevance in urban areas

Cities are dependent on water for their existence. Since the beginning of civilization, cities have been built along rivers or water bodies, providing the inhabitants with freshwater, food, and energy. Since the birth of the first civilizations in the Middle East, cities have always been developed along rivers that were a fundamental element for agriculture. Mesopotamian cultures developed along the Tigris and Euphrates rivers while the Egyptians along the river Nile.
In Roman times, there was a qualitative leap in the management of water in the city with the birth of hydraulic science (Culligan, 2020). The Romans developed a robust system of aqueducts to divert the clean water from the mountains and hills in the region around the city and transport it to Rome and make the city healthier.
The development of contemporary methods of water treatment in cities started at the end of the 18th century with the beginning of the Industrial Revolution. The rapid growth of industrial cities led to the creation of unsanitary slums with no public services, into which immigrant populations were crammed (Rodríguez et al., 2015). The resulting health problems pushed experts to pursue urbanization projects (paving, sanitation, and provisions), which involved the underground channelling of rainwater and sewage. With the impermeabilization of urban surfaces, transit was made more comfortable (López de Lucio, 1993). The main projects of that period were the "Plan Haussmann" in Paris in 1853 and the "Plan Cerdá" in Barcelona in 1860. These plans aimed to eliminate street water and make road surfaces impermeable, establishing a management model that separated water treatment from urban space design. This approach to water management in cities became a fundamental principle in the 19th and 20th centuries (Rodríguez et al., 2015).

Figure 1
Children while fetching dirty water for their families in London's slums
(© British Newspaper Archive)
In 1849, the journalist Henry Mayhew paid a visit to one London slum. His subsequent report, *In a Visit to the Cholera District of Bermondsey* (Mayhew, 1849), he described the filthy conditions of the 'wretched people'. Shocking was that children not only bathed in the same sewer water, but that he witnessed some people taking water out of it.

Between the 19th and 20th centuries, the rise of the environmental movement brought environmental concerns and ecological planning methods into the mainstream of landscape architecture, city planning, and public policy. A new vision of the relationship between planning, open space, and water was promoted. The alternative method was the creation of new "green corridors" and organized networks of parks. The main projects were Central Park and Prospect Park in New York, Riverside and South Park in Chicago, and Esmerald Necklace in Boston.
It was during the 80s with the introduction of the "Ecological Urbanism" (Stearns & Montag, 1975) concept that cities were considered capable of adapting to conditions and changing needs. Hence, water became an important variable to be considered. The introduction of "Ecological Urbanism" was the starting point of a process that later developed the concept of Waster Sensitive Urban Design.

1.2 Conventional stormwater management in cities

Water plays a significant role in everyday life. Under natural conditions, water operates in a cycle of precipitation, infiltration, surface runoff, and evaporation. In the previous section, it was underlined that at the beginning of the industrial revolution the slums in cities had poor hygienic conditions, which led to the spread of cholera epidemics. The dramatic situation in which workers lived pushed planners to introduce new ways of planning cities. The experts acquired more awareness about the situation promoting the reduction of stagnant water with the impermeabilization of urban surfaces. The impermeabilization, with the construction of underground systems of aqueducts and sewers, is still the primary method of manage water in urban areas.
With the rise of climate change related issues, new ways of treating urban drainage are required, going beyond the traditional idea of "sanitizing the city" (Rodriguez et al., 2014). The increase of flood and drought events has led people to rediscover the importance of water in the city as the natural water cycle is haltered and cannot run its course in urban areas (Hoyer et al., 2011). In rural areas, impermeable surface coverage may only be 1 or 2 %. In residential areas, this coverage ranges from about 10 in low-density suburban areas to over 50 % in multi-family communities. In industrial and commercial areas, coverage rises above 70%. In dense metropolises, it even

reaches over 90 % (Schueler 2000). It cannot infiltrate the ground, so it is rapidly collected and discharged into the public draining systems leaving no time for evaporation or infiltration (see fig. xxx). Moreover, urban water contains high level of pollutants captured during run-off on hard surfaces.

High percentage of impermeable surfaces and water pollution have negative impacts on groundwater quality, water supplies, the qualitative and quantitative state of receiving rivers. To avoid the problem of water pollution, cities have mainly developed two types of sewage systems in order to purify the waters (Hoyer et al., 2011):

- Combined sewerage systems: Wastewater and stormwater are collected in one pipe network. This mixed water is directed to the wastewater treatment plant, then cleaned and discharged into the river.
- Separate sewerage systems: Wastewater and stormwater are collected in two separate networks. The wastewater is directed to the wastewater treatment plant while the stormwater pipe directly discharges into the receiving water (in case it does not contain pollutants) or is treated separately before being discharged into the river. (Heber 1998, p. 4f.; Ganther 2002, p. 72ff.)

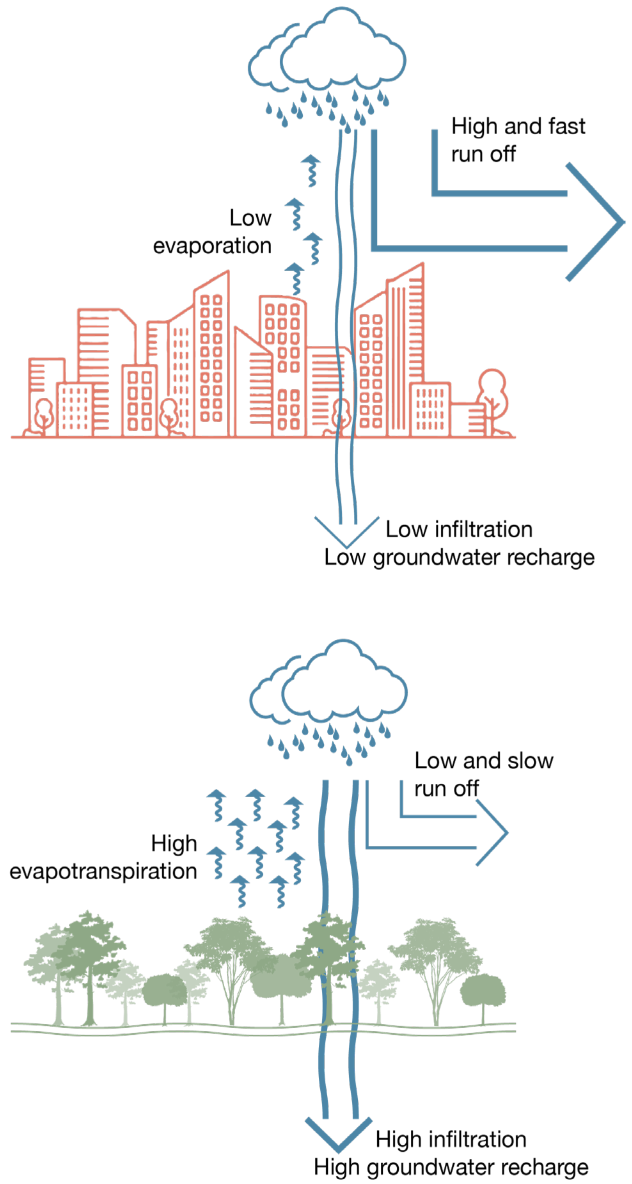


Figure 2
Runoff, infiltration and evaporation rates in urban areas (top) in comparison to natural systems (bottom)
(© Author; based on HCU Hamburg,)

1.3 Flooding problems

"Climate change is for sure the most important challenge of our generation" (Schramek C., Harmeling S., 2016, p 5). Considering climate change only as the increase in the average world temperature is a mistake because this process is also behind other extreme weather events like heatwaves, flooding and drought.

Due to climate change, there has been a modification in the distribution and the intensity of rainfall. From the beginning of the 20th century, an increase of rain from 10% to 40% has been observed in the northern European regions, while at the same time a decrease of 20% has occurred in the southern part of Europe (EEA, 2008). Forecasts predict that extreme weather events such as heavy rain and drought will increase in the future; dry regions will become increasingly dry and the wet areas will become even more humid (IPCC, 2013).

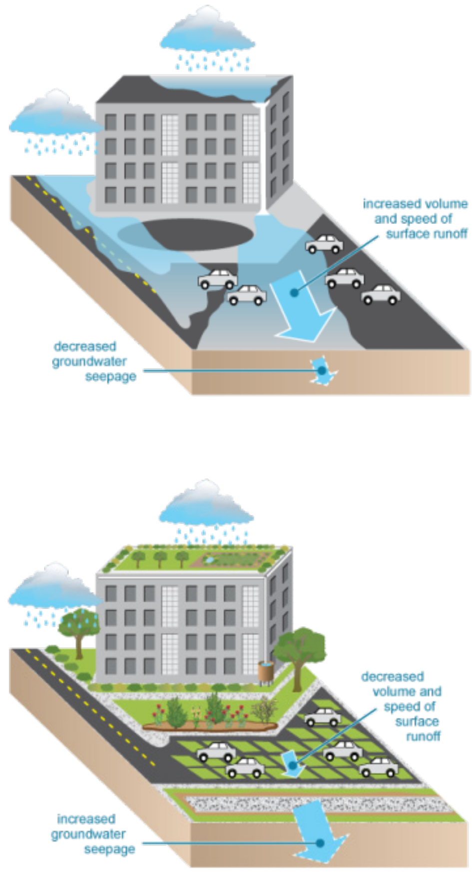
Generally, current conventional stormwater management systems are neither sustainable nor adaptable to changing climates or urban development. These systems need to be modern and efficient to quickly collect stormwater runoff from the impermeable surfaces.

These highly specialized systems have improved over time, and cities are heavily reliant on them, but there are still several issues to be tackled, such as (Hoyer et al., 2011):

- The reduction of groundwater infiltration and a lower groundwater recharge rate. Moreover, a decreasing groundwater recharge rate can limit the available drinking water in cities;
- Sewer systems can exacerbate flood conditions during periods of heavy rain, causing overflows to receive rivers. Storm sewer overflow increases the spread of pollution that was captured by flowing on the surfaces;
- Incapacity to adapt to uncertain or changing conditions from increased city development and climate change, leading to unmanageable stormwater runoff. Adapting to these changes call for higher running costs and investments, which municipalities may not be able to afford.

The Water Sensitive Urban Design (WSUD) constitute a new approach to face future challenges in the urban areas and manage better the above listed issues. The WSUD is not only a new approach for the water management, but it has also a pedagogical approach toward citizen. With many of the water systems underground in conventional stormwater management, residents and inhabitants are less likely to understand and appreciate stormwater management. WSUD promotes the use of water as an aesthetic element for the neighbourhood. Water sensitivity can significantly change attitudes promoting the intelligent use of water resources and citizen involvement (Wong, 2006).

Figure 3
Comparison between impervious (left) and pervious (right) surfaces in urban areas
(© Metro Vancouver)
Impervious surfaces reduce the infiltration of the stormwater in the ground, increasing the probability of flooding. The use of WSUD tools permits storing the water in the area without stressed the sewer system.



1.4 Water Sensitive Urban Design

1.4.1 Definition

"Water Sensitive Urban Design (WSUD) is the interdisciplinary cooperation between water management, urban design, and landscape planning. It considers all parts of the urban water cycle and combines the functionality of water management with principles of urban design. WSUD develops integrative strategies for ecological, economic, social, and cultural sustainability" (Hoyer et al., 2011, p. 14). As opposed to conventional drainage approaches, which treat stormwater as a nuisance to be removed from the urban area as quickly as possible, the sustainable management of stormwater sees it as a multifunctional resource (Mitchell, 2006). The new strategy of WSUD was introduced at the beginning of the 90s and is based on the idea to introduce greener in cities improving the permeability of the surfaces (Rodríguez et al., 2014).
The implementation of sustainable stormwater management involves measures at different scales. It starts from regional and urban planning, where the siting of different land uses can be determined according to topographical and hydrological conditions, down to the construction of individual installations or best management practices (Carmon and Shamir, 2010). The idea is to reduce stormwater runoff by treating the stormwater as close to the source as possible, ideally on-site (Hoyer et al., 2011). "Treat" in this case does not mean to collect and discharge the stormwater into the public sewer system, as it would be treated conventionally. In WSUD "Treat" means reduce runoff by using technologies for stormwater collection (e.g. for utilization or storage) and increase stormwater infiltration and evaporation. This concept aims to close the loop, bringing water back to a nature-oriented water cycle in the city.
WSUD considers all parts of the water cycle but stormwater is a key element, both as a resource and for the protection of receiving rivers (Melbourne Water, 2005). In turn, decentralized stormwater management can benefit from integrating into urban design demands. For that reason, the WSUD approach is predominantly applied to urban stormwater management that aims to recreate a natural-oriented water cycle while contributing to the amenity of the city.
The Victorian Stormwater Committee published at the end of the 90s the "Urban Stormwater - Best Practice Environmental Management Guidelines" (The Urban Stormwater Best Practice Environmental Management Guidelines 1999). According to it, the goals of WSUD from a stormwater management and planning perspective are:

- Protection of natural water systems within urban developments;
- Protection of the water quality by using filtration and retention techniques;
- Reduction of stormwater runoff and peak flows by using local detention and retention measures and minimizing impervious areas;
- Reduction of drainage infrastructure and the related development costs, whilst improving sustainability and amenity of urban areas;
- Integration of stormwater management into the landscape by incorporating multiple-use corridors that contribute to the visual and recreational amenity of urban areas.

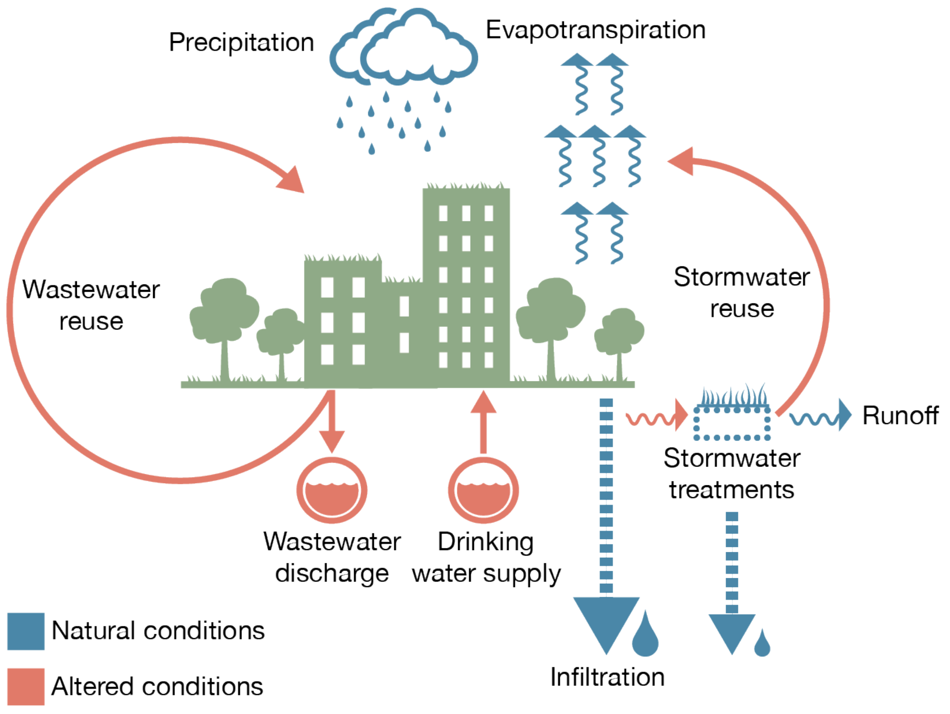


Figure 4
Waters Sensitive Urban Design balance
(© Author; based on Hoban & Wong, 2006)

1.4.2 Background

The on-going urbanization process has led an uncontrolled increase in impermeable surfaces (Rodríguez et al., 2014). The results of this has severe consequences for cities and their residents (Houšková & Montanarella, 2008; Tóth et al., 2008). At the same time, a loss of biodiversity and natural habitats (Carsjens & Van Lier, 2002; Gibb & Hochuli, 2002), agricultural and forestry land (Morello et al., 2000; Chen et al., 2003) is also occurring. The high percentage of impermeable surfaces in cities promotes a deficiency in green areas and trees able to generate a comfortable microclimate thanks to the evapotranspiration process. For these reasons, the temperature

increased in urban environments (the "Heat Island" effect), generating problems for human health.
At the beginning of the 90s, new ways of treating urban drainage were proposed, going beyond the traditional idea of "sanitizing the city" (Rodríguez et al., 2014) that promotes high percentage of impermeable surfaces. The new strategy wants to introduce more green in cities reducing the percentage of impermeable surfaces. At that time there was a rapid growth of terms such as low impact development (Department of Environmental Resources, 1999), Sustainable Urban Drainage Systems (SUDS) (CIRIA C697, 2007; MWB, 2013), Best Management Practices (BMPs) (Schueler, 1987), alternative techniques (Azzout et al., 1994) or LID (Low Impact Development).
The implementation of SUDS has proved to be a handy tool for integrating water in urban processes. Afterwards, the concept of SUDS has been renamed as "Water Sensitive Urban Design" (WSUD) (Rodríguez et al., 2015). WSUD was used for the first time at the end of the 90s in Australia (Mouritz, 1992). The evolution of the name permits to combine the only consideration of the sustainability of water management with the principles of urban design that promote aesthetic benefits (Hoyer et al., 2011 pag. 14).

Figure 5 and 6
IBA Emscher Park
(© Internationale Bauausstellungen website)
This IBA had the aim of giving the central Ruhr area impulses for responding to the industrial decline of the region. Landscape planning and urban development projects were implemented for the ecological, economic and cultural renewal. In IBA Emscher Park for the first time were implemented WSUD tools in Germany.

The use of the term WSUD started in Australia during 90s and then immediately spread in other countries (Fletcher et al., 2015). In Germany, the WSUD was introduced from the International Building Exhibition "IBA Emscher Park" at the end of the 90s). In the beginning, was called "Alternativen zur Regenwasserableitung" (alternatives to stormwater drainage) which shows the paradigm shift from the traditional storm water management system to the new water sensitive approach (Grote- husmann et al., 1994). Over time, new terms such as Regenwasserbewirtschaftung (stormwater management) were developed that emphasize the aim of maintaining pre-development hydrology via source-control based stormwater management. Now the concept that is more used is dezentrale Regenwasserbewirtschaftung (decentralized stormwater management) (Schmitt, 2007). These concepts are highlighted by the German national stormwater management guidelines (DWA-A 100, 2006) as a necessary component of integrated stormwater management.
The concept evolution explained above states the long history that Germany has in the water management approach. The first regulation regarding water management were developed already in the 19th century. The first attempt to establish a federal water law occurred during the National Socialist era in the 30s, but it was necessary to wait until 1960 to see the first national law that has now been replaced with the WHG 2009. The Wasserhaushaltsgesetz (2009) is a federal framework law, and the individual states can diverge by specifying it better. The law establishes clear directives for water resource management including groundwater pollution and degradation, urban wastewater treatment, environmental protection, and flood risks. For years before this law, water-sensitive or "decentralized" solutions had been a water management goal. With the introduction of the Wasserhaushaltsgesetz in 2009, decentralized methods are now to be considered first and implemented when possible. Interesting is also the introduction of the German Waste Water Levy Act (Abwasserabgabengesetz 2009). The Abwasserabgabengesetz regulates the responsibility to pay taxes for the discharge of wastewater (dirty water, rainwater) into channels or rivers. This law strongly follows the "polluter pays" principle (Hoyer et al., 2011). It is the first nationwide environmental tax and places the financial responsibility of clean-up on polluters.

1.4.4 WSUD in comparison with related concepts

The concept of WSUD has some relationship with other terms that arose in the last decades after a more deepen attention to the environmental issues due to climate change. This section will analyze the meaning of the other related concepts and how they are related to WSUD. These concepts are landscape urbanism, ecological urbanism, design for resilience, and green and blue infrastructure.

Landscape urbanism start from the assumption that in traditional urbanism, structures like walls, roads, or buildings, led the development. Green spaces were relegated in an unsuited area for building or were used for ornament. Landscape urbanism argued that the city is constructed by ecological interconnections that help the designer to organize urban form (Steiner, 2011). This concept was mainly developed by Charles Waldheim that also coined the term (Waldheim, 2006 & Almy, 2007). Waldheim was a student in architecture during the 80s. He was influenced by the ideas of McHarg that at the time was discussing the future of landscape architecture.

There are still few projects developed following the ideas of landscape urbanism and one of the most famous is the High Line in New York where an ex elevated train line was redeveloped in a linear park. Landscape urbanists are interested in giving to nature and people the same importance and the same space inside the urban structure considering aspects like culture and economy (Steiner, 2011). The High Line project is the perfect example because an abandoned area was redeveloped introducing a new landscape into the metropole where people and nature share the space. The redevelopment of the area promoted the construction of a tourist attraction and a generator of economic development.

Comparing the concept of landscape urbanism with WSUD, is it possible to state that the seconds one focus more the attention on the capacity to reestablish the natural water cycle inside the urban area. Landscape urbanism, like WSUD, is also an interdisciplinary approach that incorporates ecology, engineering, and landscape architecture. Stormwater management is also considered in some landscape urbanism projects as an organizing principle. The difference is that in WSUD, everything turns around the water management not just as an aesthetic and natural element for the design of the projects. The idea, in WSUD, is to make the water visible and treat it as much as possible into the site to not discharge it into the sewer system.

Figure 7
High Line New York
(© Pinterest)

Ecological urbanism foregrounds a view of the city as a metaphorical ecosystem. The idea is to develop artificial ecosystem to give to the urban areas the possibility to achieve the same efficiency and life-preserving redundancy of natural ecosystem (Hagan, 2015). Ecological urbanism is a late entry into the field of ecology, and it aims to be an ideal bridge between urbanism and ecology.

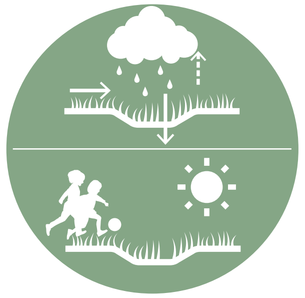
The term appears for the first time in 1999 in a book of the Spanish architect Miguel Ruano called “Ecourbanismo, entornos humanos sostenibles: 60 proyectos (Ecourbanism, sustainable human environments: 60 projects). In the next years, the concept was used in several other publications, but Iranian American architect Mohsen Mostafavi was the author that promoted the development

of ecological urbanism (Mostafavi, 2007). Mostafavi was the author that mainly contributed to the emergence of both the concept of landscape urbanism and ecological urbanism into the architectural debate. In many ways, ecological urbanism can be considered an evolution of landscape urbanism. This second concept mainly considered the landscape into the city and the balance between human and natural needs, while ecological urbanism wants to bring to the table the ecological (Hagan, 2015) expertise and consider the urban areas as an ecological system (Steiner, 2011).
Even the concept of ecological urbanism has some relation with WSUD. The ecology is one of the fields that are involved in the implementation of WSUD projects to develop biotopes that ideally recreate the traditional environment of the region where they are located. In WSUD, everything turns around the ability to maintain the natural water cycle inside the cities, so the role of these biotopes is to treat the water and make it clean.

Urban resilience is a concept that started to be used in the last years after the rise of the resilience concept in urban planning and design. The concept of resilience was born during the 1970s by ecology scholars that introduced the concept of engineering resilience. One of the "pioneer" articles about these arguments is the one written by Holling that introduces the concept of Engineering Resilience. Engineering resilience is defined as the ability of a system to return to equilibrium or steady-state after a disturbance" (Holling, 1973, 1986), "which could be either a natural disaster, such as flooding or earthquakes or social upheaval, such as banking crises, wars or revolutions" (Davudi, 2012).
After the introduction of Engineering resilience, the concept started to evolve with the introduction of Ecological resilience that focuses more on "the ability to persist and the ability to adapt" (Adger, 2003, p. 1) in order to find a new level of stability. Then was introduced the concept of Equilibrium resilience that tried to find a relationship between the previous two concepts, a relationship represented by the capacity to reach equilibrium after the shock (Davudi, 2012). Finally, in the concept of Evolutionary resilience, it is not possible to bounce back to the previous normal state. This because after the shock, the systems change; they adapt and transform themselves in response to stress (Carpenter et al., 2005).
In the last years, the popularity of the term resilience increased significantly, and it appears in every kind of subject Gabellini (2018). Focusing the attention on urban resilience it is considered "the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity" (Meerow et al. in 2016). Basically, urban resilience is based on four "fixed points" that are (Buffa, 2016): complexity, unpredictability, process (capacity to adapt and change after a shock), and openness (capacity to imagine new possible future after the shock).
Until now, there is still not a common definition of resilience. This word can be considered an umbrella under which all the definitions enclosed (Meerow et al. in 2016). Specifically, WSUD could be inserted under the umbrella of the urban resilience concept. As the definition says, WSUD develops integrative strategies for ecological, economic, social, and cultural sustainability. Sustainability is the final goal for the evolution of the urban system and resilience is a tool that can help to go in the desire direction. WSUD can be considered a concept under the umbrella of urban resilience that focuses specifically the attention on the maintenance of the natural water cycle inside cities. WSUD give to the urban areas the capacity to adapt and change (as the definition of urban resilience says) in case of intense stormwater events.

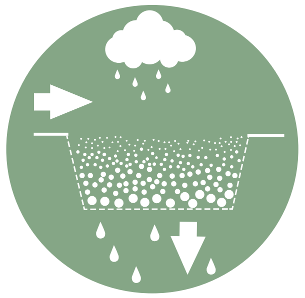
Blue- green infrastructure are a well-established concept while awareness and understanding of its potential benefits have increased (Wouters et al., 2016).
The term green infrastructure often refers to projects that include vegetated design elements. These green infrastructures provide important ecosystem services valuable in densely populated urban areas. This concept cannot give a complete overview as infrastructures of this type are often closely linked with "blue infrastructure". Blue infrastructure technically refers to those related to the hydrological functions, including rainwater and urban stormwater systems as well as surface water and groundwater aquifers. The concept of blue-green infrastructure is a connection between the two concepts in a union that is greater than the sum of its parts (Wouters et al., 2016). Often blue-green infrastructure concept is used as a synonymous of WSUD but there is a small difference between them. Both describe green infrastructures that temporarily turns "blue" during rainfall events and floods (Sinnett et al., 2015). WSUD aims to recreate the natural water cycle inside urban areas and is based on the integration of the water cycle planning with urban design (Galvis-Castaño, 2019). In particular, WSUD wants to decrease the percentage of impermeable surfaces in order to reduce the runoff and make the urban area more adaptable in case of climate change.

Rainwater harvesting



Bio-retention areas

Biotopes



Gravel or sand filters

Rooftop retention

1.4.5 WSUD tools

There are many solutions to promote stormwater management. Every case study is different, and the ideal solution is often a combination of several methods (Woods-Ballard et al., 2007).
Below there is a list of WSUD tools that are organized in the five categories. The organization into categories considered the primary function of the WSUD tools (Hoyer et al., 2011):

- rainwater use
- treatment
- detention and infiltration
- conveyance
- evapotranspiration

Rainwater use

Rainwater used directly on-site wastes less energy on transportation and promotes the development of a decentralized system. Decentralization is helpful because, in case of a problem in the central system, it can for compensate the lack of water.
One of the main design elements is :

- *Rainwater harvesting.* It can be underground or aboveground and it is typically a larger storage device. The water can be used for the supply in toilets, for the fire sprinklers when treated, or for garden irrigation.Above-ground storage systems can incorporate tools to store and filter water for use in gardens or as potable water. The above-ground elements can be part of the landscape and architectural design such as fountains or pools.

Treatment

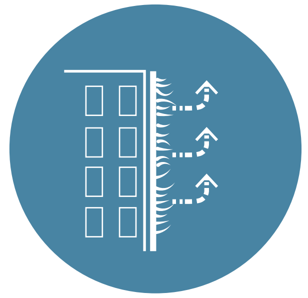
Stormwater treatment is a fundamental step before re-using water for domestic purposes or before infiltration in the ground.
Several design elements permit the treatment and are listed below:

- *Bio-retention areas*: are landscaped depressions where the vegetation inside them filtrates the water to remove the pollution. Inside these areas, it is possible to plant different types of vegetation that improve the landscape quality and retain and purify the water. When Not flooded, the areas can be used for recreation.
- *Biotopes*: consists of a landscape of plants and sometimes animals deliberately assembled for ecological stability. Biotopes can be used to improve water quality through, for example, natural oxygenation. These elements also enhance the quality of the landscape of ponds or water features because they can be placed to shelter a site from wind or unpleasant views and frame public spaces or walking paths.
- *Gravel or sand filters*: can be a first filtration element to treat surface water runoff by using gravel or sand.

Detention and infiltration

The detention of water is important to reduce the surface water flow and the stress on stormwater sewers. The detention tools temporarily store water and gradually infiltrate it by using the following elements:

- *Rooftop retention*: it is also called green roofs and are a multilayered element generally intended to mitigate habitat loss in new developments. A green roof could become part of the landscape and or even an accessible garden. They are also useful to better insulate the building and to reduce the heat island effect;
- *Green facade:* is a vertical vegetative system which can be created applying self-climbing plants, plants grown in garden beds at its base, plants grown from pots attached to the façade or from a substrate. The construction includes a water delivery system and the modular elements contain substrate space and automatic irrigation.
- *Permeable paving*: are paving in concrete or asphalt that allow water to pass through, thanks to a subgrade gravel bed or another porous medium. These kinds of paving retain water in the subgrade, where it can then infiltrate into the ground, evaporate, or be drained from the system. It can also be used in the street to reduce the speed of cars;
- *Infiltration zones and trenches*: they are planted spaces designed for the retention and the rapid infiltration of the surface water during storms. They are generally made using gravel, sand, and other minerals or substructures and can be used in every kind of urban space. Infiltration zones and trenches can be used to beautify a neighbourhood, especially those that are heavily paved. Typical applications are street planters and rain gardens;
- *Swales:* the difference with the previous tool is that they are linear elements which store or convey surface water. They generally have an impermeable substrate because they are designed only for water transportation and downstream management. The delicate slope of the swales could be used for recreation when dry;
- *Geo-cellular systems:* prefabricated structures installed underground to store and slowly infiltrate stormwater. They are useful in high-density urban areas because they can collect a lot of water but are invisible on the street surface;
- *Detention pond (dry):* surface storage basins that attenuate and hold stormwater runoff. These elements are generally dry and use as recreational spaces until the rain period when the water is



Green facade

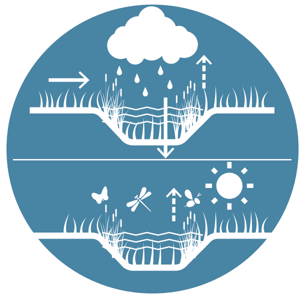
Permeable paving

Infiltration zones and trenches

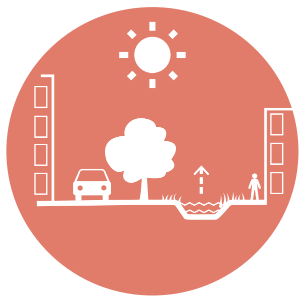
Swales

Geo-cellular system

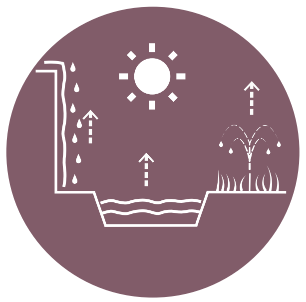

Detention point (dry)


Detention point (wet)


Water square


Open stormwater canals/ drains


Passive evapotranspiration


Active evapotranspiration

collected in the pond and slowly infiltrated in the ground;

- *Detention pond (wet):* the difference with the previous example is that they store rainwater and consistently hold it. They could also have biotopes to filtrate and improve water quality.
- *Water square:* it is an innovative answer to the need of manage water in square with high percentage of impermeable surfaces. They have a double function. Generally the square is a playground area, but during the storm it becomes a water retention basin.

Conveyance

The conveyances are just elements for the transportation of the water.

- *Open stormwater canals/ drains:* They are an alternative to the underground sewers. These elements are useful in the design of the urban areas because they drastically change the perception of urban space, thus educating viewers on the water cycle.

Evapotranspiration

Evapotranspiration is an essential step in the water cycle. The high percentage of paved surfaces in the urban areas remarkably reduces this step, increasing the heat island effect. With WSUD, the idea is to increase the green and porous surface to promote a better evapotranspiration process even in the cities. There are two kinds of evapotranspiration:

- *Passive evapotranspiration:* This process refers to the concept of utilizing the inherent qualities like transpiration and evaporation to improve the indoor and outdoor climate. Every kind of vegetative element in urban areas is useful to promote this process.
- *Active evapotranspiration:* this process is promoted by using rainwater walls, fountains, and pools. Basically, the movement of the water directly changes or influences the temperature or air quality of public spaces or within buildings and also improves the quality of the design in the project.

1.5 Criteria for project analysis

1.5.1 Overview

In the previous sections, WSUD and the decentralization of the water system was analysed to see how it could be useful to improve the quality of stormwater management. The use of the WSUD tools is still not common mainly due (Hoyer et al., 2011):

- *Lack of implementation*: the use of WSUD solutions in recent years has been supported by governments but is still not often implemented because conventional solutions are preferred and getting the license to perform a WSUD project is complicated.
- *Missing or lacking integrated approaches:* the use of WSUD approaches requires the cooperation of several experts in different disciplines like urban planning, architecture, engineering, and landscape planning. This is not always a common practice, but it is necessary to promote a good project and contributing to the aesthetics and amenity of urban areas.
- *Lack of knowledge, acceptance and awareness:* the inhabitants and the stockholders involved in the transformations (and often even the experts) are not conscious of the advantages of the WSUD approach. The techniques used are not only useful to promote better water management, but they also have a social and educational value. The aesthetical quality of the projects and the value that the water acquires are useful for bringing the inhabitants closer to nature.

1.5.2 SWITCH European project

In the following section will be identified the criteria for the project's analysis in chapter 2. They are identified starting from the manual made by the scholars of the HafenCity University in Hamburg (Hoyer et al., 2011). These criteria were developed within the scope the project SWITCH, an European project focussed on innovation in the area of sustainable urban water management. SWITCH was a major research partnership funded by the European Commission over the period 2006 to 2011. It involved an implementing consortium of 33 partners from 15 countries promoting innovation in the area of sustainable urban water management. This ambitious project looked towards water management in the 'city of the future' aimed to challenge existing paradigms and to find and promote more sustainable alternatives to the conventional ways of managing urban water. The SWITCH project included thematises like:

- Cities in four continents and at various stages of development
- All aspects of the water cycle (water, wastewater, stormwater and natural systems)
- A wide range of climatic, socio-economic and institutional situations
- Social, economic and environmental perspectives
- Scales ranging from household to city levels
- Water as part of urban planning and the built environment
- From the present time to the 'City of the Future'

Within the scope of SWITCH, HafenCity University of Hamburg researched in the field of WSUD. The main research question that the university wanted to answer were:

- What is Water Sensitive Urban Design?
- What principles need to be considered when applying WSUD?
- What does WSUD look like?

The main intention was to elaborate a manual able to inspire stakeholders involved in the lanning, design, and maintenance of stormwater management in urban areas. The aim of the manual was to put more sustainable stormwater management into practice improving also the aesthetic quality of the public spaces (Hoyer et al., 2011).

1.5.3 Criteria overview

In the following list there is the explanation of the criteria that the scholars of the HafenCity university identified as the base of WSUD. The criteria are:

- *Water sensitivity:* Generally, urban water should be managed as close to the source as possible to restore local, small-scale water systems. For this reason, it is essential to retain water at the site during the storm, treat it, and promote high infiltration and evaporation as much as possible in the area.
- *Permeability*: WSUD needs to reach the goal of restoring or maintaining the natural water cycle in the city. In the typical urban environment, there is more runoff, less infiltration, and less evaporation. Consequently, to improve the water sensitivity of the area, it is crucial to develop surface areas able to increase the infiltration.
- *Aesthetic benefit*: The use of decentralised stormwater management measures can improve the visual aesthetics of the project area. At the same time green spaces and water are key elements for the quality of life in cities. "Cities with a high rate of green spaces and water bodies have always been leaders in terms of liveability" (Hoyer et al., 2011).
- *Integration in surrounding area:* Like any project, even for the WSUD approach, it is important to have an appropriate integration with the surroundings. The city is a collection of buildings, streets, and different landscapes that need to be well integrated.
- *Appropriate design:* Like the previous one, this indicator needs to consider the surroundings because design solutions should be developed according to the local environment. The difference is that this indicator considers the relationship with the site, including topography, ground permeability, water table levels, and water quality. The best choice for the area depends on many factors. For example, when we talk about water management, it is necessary to consider if the water should be infiltrated, restored, or used.
- *Adaptability*: Because of climate change, stormwater events are becoming more intense and are difficult to predict. Therefore, WSUD tools need to be able to adapt to different weather events and future demographic and economic conditions. At the same time, they should also be able to adapt to the existing urban infrastructure.
- *Appropriate usability:* Often the WSUD facilities need big spaces to be implemented. These spaces are difficult to find in cities that already have a defined urban structure. What helps is the possibility to implement the stormwater management areas in the outdoor recreational or conversational spaces. It is known that the WSUD tools are generally green areas that can also be recreational spaces when they are dry. In this way, the solution should aim to unite both uses in one space.
- *Public involvement*: Urban planning always tries to promote citizens' participation in developing the best solution for the study area. For WSUD the public involvement is fundamental to discussing the advantages and disadvantages of decentralized stormwater management and hopefully to eliminating prejudices.
- *Interdisciplinarity*: it is known that the WSUD concept involves several professionals like architecture, urban planning, and landscape planning, but also ecology, engineering, etc. Therefore, it is necessary to promote a multidisciplinary team for the design of WSUD projects, which cooperates as early as possible in the planning process and subsequently at various planning levels.

Chapter 2

European examples

2.1 Augustenborg (Malmö)

2.1.1 Background

Malmö is the third-largest city in Sweden with 300.000 inhabitants, but the entire metropolitan region is home to over 700,000 people. Thanks to the city's strategic position on the Öresund channel Malmö has been an essential marketplace. With the construction of the modern harbour at the end of the 18th century and the railway connection in the middle of the 19th century, Malmö developed into an industrial centre. During the recession period in 1970s the industrial-based economy of the city went through a severe crises. It was necessary wait until the late 1990s that signs of recovery started to appear, also thanks to public investments driven by the construction of the Öresunds Bridge (1995 – 2000).
Malmö is, along with the city of Copenhagen, part of the Öresunds Region that is home to over 4 million people, so the construction of the bridge was essential for the development of the area.

2.1.2 From "neighborhood units" district to Ekostaden

In the period after the bridge's construction, the city started to reconvert all the industrial areas into university campuses, parks, and residential areas, giving a new face to the city. On the other hands, some of the existing neighborhoods were reconverted in eco-districts with the involvement of the residents. One of the most famous examples is the neighborhood of Augustenborg, built between 1948 and 1952 as the first public housing area in Malmö. The planners were inspired by the English and American idea of "neighborhood units." The unit is a "city in the city" that is almost self-sufficient with its coal-fuelled central-heating power plant. There are all the essential services like markets, schools, parks, and squares but also shops, banks, a post office, etc. When it was planned, unique "sun-studies" were done to get optimal conditions for playgrounds and yards (Rolfsdotter C., Jansson Damanco Community, 2010).

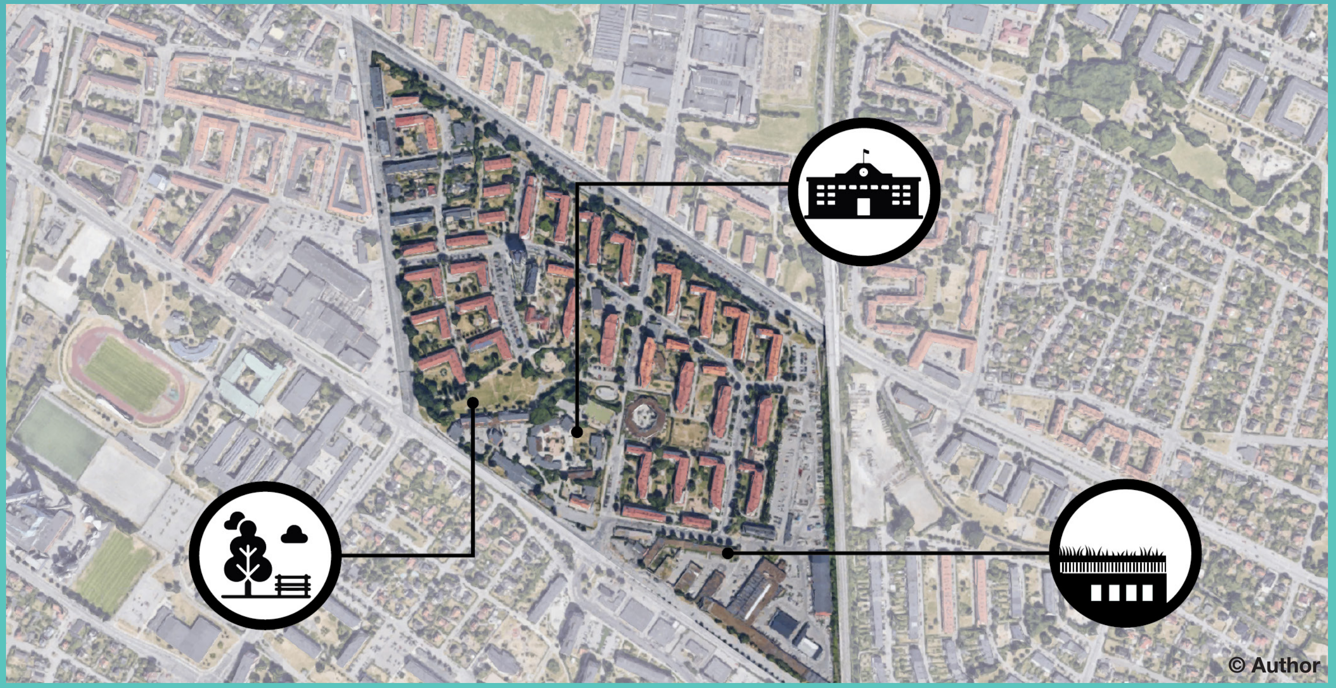
BOX 1 - EKOSTADEN

Immediately after the construction, flood problems began to arise in Augustenborg. After the initial enthusiasm, the area began to show social issues like unemployment and segregation, and by the end of the 80s, the neighborhood had lost its popularity.
The Ekostaden Augustenborg project began in 1998, aiming to make Augustenborg a more socially, economically, and ecologically sustainable housing area. To improve the regeneration project's quality, the citizens were involved in the process. Up to a fifth of residents assisted in the project's dialogue meetings. The main problem for the residents was to lower the cost of living. Hence, they focused on reducing energy consumption, partially by behavioural changes, partially by technical solutions. To solve the flooding problem, the construction of green roofs and open stormwater systems was promoted.
The idea of Ekostaden was that Augustenborg could become the family area it used to be because of the abundance of nice playgrounds and greenery. Augustenborg was a pioneer area when it was built, and through the Ekostaden project, it again played a leading role in urban development. The outcomes of the project became learning elements for the development of the other areas of Malmö.

Augustenborg park

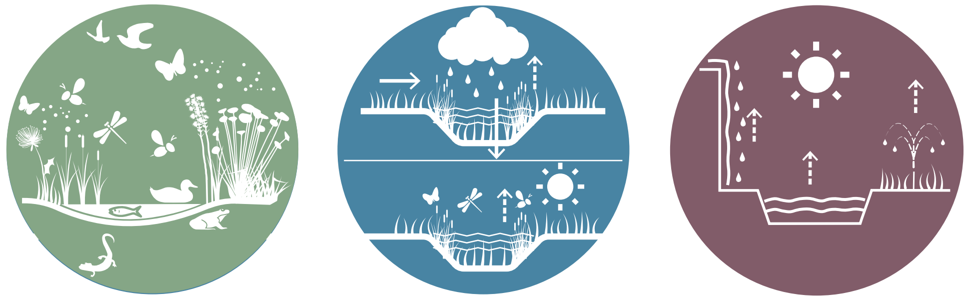
Augustenborg school pavillion

Augustenborg green roof institute



2.1.3 Tools overview

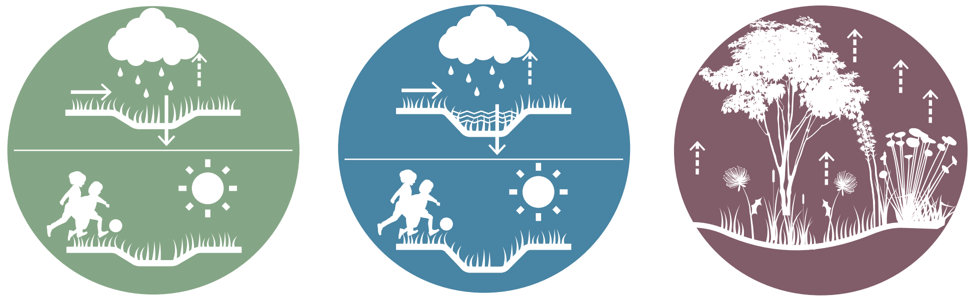
Park's lake



Biotopes · Detention point (wet) · Active evapotranspiration

The lake is a wet detention point where there is water for the entire year. Several vegetation elements permit to have a biotope with different species of animals inside. The presence of water for the entire year permits active evaporation.

Detention points (Dry)



Bio-retention areas · Detention point (dry) · Passive evapotranspiration

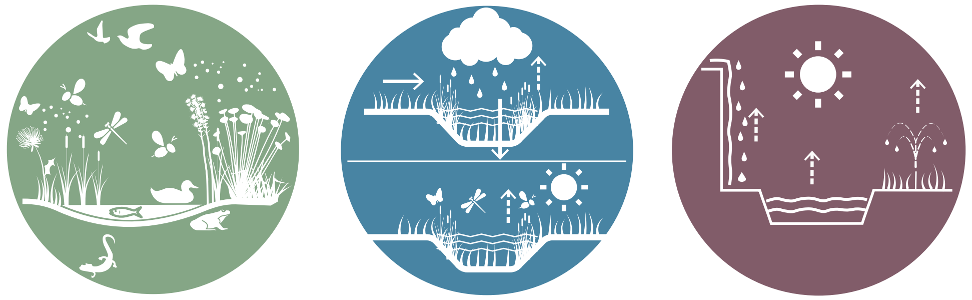
They work in collaboration with the canals. When the water overflows the canals it enters into the detention points where it is treated. The different species of green create bio-retantion area that can treats the water .

Street trenches

Infiltration zones and trenches · Passive evapotranspiration

The trenches permit to collects the water from the streets and the sidewalks during the storm. Since there is no water during a normal sunny day, evaporation is passive and is permitted thanks to the natural process of the vegetation.

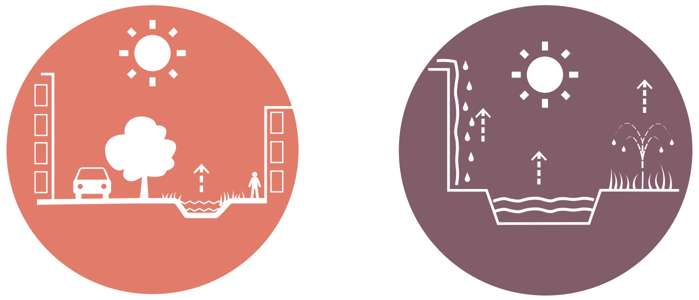
Detention points (Wet)



Biotopes · Detention point (wet) · Active evapotranspiration

They have the same function as the lake's park but are smaller. They collect the water from the private green areas. The fountains permit and active evaporation.

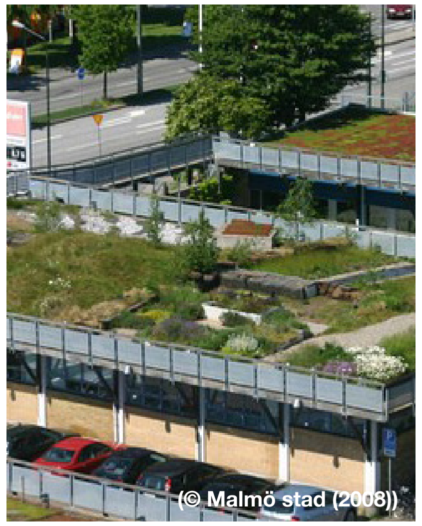
Watercanals



Open stormwater canals/ drains · Active evapotranspiration

Several canals distributed in the district collect the water from the green. The movement of the water permits active evaporation.

Green roofs



Rooftop retention · Passive evapotranspiration

In the district there are more than thirty green roofs that can sensibly reduce the water runoff. The vegetation permits passive evaporation improving the microclimate quality.

2.1.4 Criteria application

Water sensitivity

In order to divert water from the city's sewage system during extreme flood events, planners decided to make the water cycle visible. Small channels were created to collect the water from the green areas while swales, made from concrete elements, accumulated the water from the impermeable surfaces. All these elements were used to transport stormwater in the direction of several wet detention points distributed along the entire site area. The detention points were structured as bio-retention areas or biotopes, spaces were the water could be treated before infiltrating in the ground.
The case of Augustenborg's school is especially interesting thanks to the array of eco-solutions adopted. The different parts of the outdoor area are separated from each other by green zones and playgrounds. Open stormwater drains in the green area and on the schoolyard lead water into a pond where the children can explore small underwater creatures. The schoolyard had been mostly covered by asphalt before the Ekostaden project started. Now there are new trees and an outdoor classroom where the children can sit outside and study, as well as new stormwater channels that on stormy days turn into the waterfalls. The students took part in this transformation by planning the original design of the garden.
The use of WSUD tools like swales and wet detention points is useful to maintain the rainwater on the site. Unfortunately, there is still a lot of it coming from the roofs of the buildings. The green roofs are used to solve this problem. A green roof is created by sowing or planting directly on a layer of soil, or by placing prefabricated green mats on the roof. The thickness for moss roofs varies from 2-5 cm, and for grass and herb roofs from 7-15 cm. Advancing this concept further, the world's first botanical roof garden was opened in Augustenborg in 2001. The garden is an exhibition and research facility covering more than 9 000 m2 and aims to promote the use of lightweight vegetation layers on roofs in Scandinavia. This roof garden is on the top of the Scandinavian Green Roof Institute, one of the most important in the world regarding the research on this topic. In addition to the Roof Garden of the institute, there are around 30 other green roofs in the area. Fifty percent of the rainwater is taken care by the thin green roofs, and this represents a major burden off the city's stormwater system that does not need to be conveyed to the sewers.

Permeability

A high percentage of greenery already covered the neighbourhood of Augustenborg in the initial plan of 1940s & 50s. The park and several gardens were already essential elements to contain the water in the site - instead of conveying water to the city's sewers and closing the water cycle - permitting evapotranspiration and permeability. The Ekostaden project provide additional tools for the green space, implementing WSUD elements like swales and wet detention points. They are able to manage better the water directing it in retention areas where it can be collected. Previously, the water could infiltrate the ground through the greenery or flow along the impermeable surfaces and end up in sewers. Now, the detention points can also be used to collect water in ponds and allow it to slowly penetrate in the ground after the storm.

Aesthetic benefit

The several green areas developed since the construction of the neighbourhood already provide important aesthetic value to the area. The adding of WSUD tools gave the possibility to make the water cycle visible. Several water plants can treat the water and at the same time improve the quality of the landscape by framing public spaces or walking paths. These tools also function as a learning element because they help citizens to better understand the importance of the water cycle in urban areas. The school is an interesting example because the kids projected how the water elements should be in the school's garden.
Green roofs are also exciting elements, able to improve the aesthetic benefits of the project. The plants turn green, brown, yellow, and red, depending on the time of the year. In this way, it is interesting to see how the urban landscape changes in different seasons.

Integration in surrounding area

The involvement of the city mayor in Ekostaden project was important for the good integration in the surrounding. The mayor had an architect background and he had a well understanding of the city (Malmö stad).
The greenery was already an essential element of the neighbourhood before Ekostaden. For this reason, the water-sensitive solutions were just a soft intervention without any hard infrastructure. Plants and pods were developed creating improving the variety of the natural landscape.

Even the structures introduced in the school are made of ecological materials that match with the surrounding context like the eco-pavilion where there are several classrooms. The building is entirely recyclable and can be taken apart and moved. It has a green roof, natural materials, and energy saving lights connected to movement detectors.

Appropriate design

The WSUD tools in Augustenborg closed the water cycle, increasing the evaporation and infiltration. One of the carpenters that lived in the area helped in the design of the water elements. Being familiar with the site, he developed WSUD tools with an appropriate design that keep the municipal sewage system from being severely burdened.
Probably the most interesting intervention is the introduction of green roofs. They are well integrated into a neighbourhood that already has a high percentage of greenery. They manage to capture and retain even fifty percent of the water. Thanks to these interventions, there have not been any floods in the area since the open stormwater system was installed. Augustenborg even managed well when large parts of Malmö were flooded in the summer of 2007.

Adaptability

The WSUD tools were implemented in the area to solve the flooding problems that occurred after the neighbourhood construction. In the future, stormwaters will increase in their amount and intensity. The experts and citizens think that the water management tools already implemented here could be an opportunity to face climate change. The WSUD elements already demonstrated their effectiveness by solving the previous flooding problems. At the same time, more action will be necessary in response. The introduction of systems for rainwater retention and purification is crucial for sustaining green spaces, improving air humidity, and human health, which all are fundamental for adaptation to global climate change.

Appropriate usability

Since several green areas already covered the site, it was not complicated to find the space for the implementation of the WSUD tools. The development of water management elements in the park, green areas and along the border of the streets were perfect for connecting the green necessity with the need of new rainwater tools. In this case too, the school represents an essential element of good results. The kids cooperated with the planners to design a new garden where the WSUD tools become playground elements, matching the need of water-sensitive features with the necessity of maintaining the playground area.

Public involvement

The citizen participation was a key element in the Ekostaden project. From the very beginning, the planners involved the inhabitants and they became the experts. Dialogue with the residents also created a good breeding ground for local community groups. The participation process involved all types of residents, from elderly people to children.
The involvement of the school’s students was particularly interesting since they directly participated in the change. After inspirational study visits in other districts in Malmö and in the city of Lund, they were involved in the design of their own schoolyard. New trees were planted, and special water playgrounds were built.

Interdisciplinarity

Along with public participation, interdisciplinary involvement is one of the successful elements of the project. Planners, architects, and engineers were all involved in the development of Ekostaden. The public involvement was important from the beginning because it gave fundamental feedback to the multidisciplinary team.
The contribution of the neighbourhood association and its representatives needed to have a constant dialogue with the municipality. The interest of the Mayor and chairman of the executive committee of the city of Malmö in the Ekostaden project was an essential element for a constant dialogue with the different parties involved (Malmö stad, 2020).

2.1.5 Final considerations

The following list identifies the positive elements that characterize the project and the problems that arose.

Incrementation in water sensitivity
The analysis showed that in Augustenborg several flood problems happened after the development of the area. The neighborhood is built on a site that has a higher risk of flooding, but the high quantity of green elements represents a resource for solving this problem. In this project, it was not necessary to develop new green areas to improve permeability because fortunately Augustenborg was already built giving to the inhabitants essential access to nature. Planners took advantage of this relevant quantity of nature and completely reorganize the green public spaces to increase the water sensitivity. The implementation of WSUD tools like dry and wet detention points (section 2.1.3) reduced the pressure to the sewer system. They collect the water during the storm in ground depressions distributed along the entire district, almost removing the flooding problem.

Permeability and evapotranspiration improvements
The theory of the first chapter stated the importance of the importance of green to reduce the flooding risk. The diagram in section 1.2 explains well how nature is fundamental to reduce runoff and increase infiltration into the ground. The district was already covered by a high percentage of green that retained some water in the area, but it was not enough. Reorganizing the entire water management system to solve the flooding problems was necessary. WSUD tools like canals and trenches (section 2.1.3) were introduced along the streets and sidewalks to collect the water from the impermeable surfaces.
The possibility to make the water cycle visible also promotes active evaporation of the water. The introduction of canals and detection points significantly improved the evaporation. These tools reduced the quantity of water discharged into the sewer system keeping it into the surface as much as possible and reducing the flooding problems.
The development of WSUD tools like detection points and canals probably would not have been sufficient without the implementation of green roofs. They are a key element in the project because they can retain almost 50% of the stormwater on the site.

Aesthetic improvements
The aesthetic quality of the final result is for sure another main positive element of Ekostaden Augustenborg. The good integration of the WSUD tools into the surrounding landscape and their appropriate design with wood or local material was appreciated by the inhabitants. With Ekostaden, the planners could transform a monotonous landscape where the green was mainly composed of a flat expanse of grass. The construction tools with different vegetation species and a more dynamic landscape transformed the green public spaces into a nice place to spend the free time.

Implementation problems
The implementation process was characterized by dynamics problems between individuals that had slowed down the implementation of Ekostaden. More than 3000 residents were involved in the development of the project. Hence, some inhabitants disagreed with the project ideas and created delays in the whole participation process. Moreover, serious concerns arose when the local housing company changed executive directors. The new authority lacked the in-depth understanding of the project that his predecessor had possessed (Malmö stad, 2020).
Despite the combination of the problems just mentioned, the Ekostaden project can be considered one of the best examples in Europe for the introduction of WSUD. After the construction of the neighborhood, several floods happened in Malmö but the district of Augustenborg was not touched by these extreme events. Despite the problems, the citizen involvement in the entire process gave them the awareness of the WSUD importance and still now several associations are involved in the maintenance of the public spaces.

Figure 8
Public involvement for the development of Augustenborg project
(© Malmö stad (2008))

2.2 Climateproof ZOHO (Rotterdam)

2.2.1 Background

Rotterdam is the second-largest city in the Netherlands. Alongside the municipality of The Hague, Rotterdam is the most significant metropolitan area in the country, with a population of 2,7 million. The city is famous around the world for its seaport that is the biggest in Europe. Rotterdam is localized in a strategic area of the continent because it is at the mouth of three major European rivers, the Rhine, Meuse, and Scheldt. This position gives waterway access into the heart of Western Europe, including the highly industrialized Ruhr region of Germany.
40% of the Netherlands is below sea level, although in Rotterdam, this percentage increases to 80%. Considering that, the country is famous all over the world for its ability to defend itself from the ocean's extreme events. The need to develop modern defences from the sea arose after the 1953 North Sea flood. The combination of wind, high tide, and low pressure promoted an extreme event that flooded entire regions of the country.
After that disaster, the Dutch government started the development of the Delta Works project. Delta Works is a series of construction projects in the southwest of the Netherlands to protect a large area of land around the Rhine-Meuse-Schelde. The city of Rotterdam was also involved in this project with the construction of the Maeslantkering. The Maeslantkering is a storm surge barrier constructed in 1991 that close the delta of the river on case of ocean's extreme events.
The end of the 90s was also the period in which was developed the first Waterplan called Waterplan Rotterdam 2000-2005. This was a strategic plan to promote measures for improving the relationship between the city and the water. In 2007, a new plan (Waterplan 2) was developed due to the new need to face climate change.

2.2.2 From Waterplan to climate proof Zomerhofkwartier

In 2007 the combination of several problems like the rising in sea level, the population decline, particularly among working people, and other issues like the redevelopment of older harbor areas pushed the municipality to develop a new Waterplan. The municipality vision looks ahead to 2030 with the idea of developing a city with a strong economy and an active place to live.

The aims of Rotterdam's Waterplan 2 are (Municipality of Rotterdam et al. 2007a):

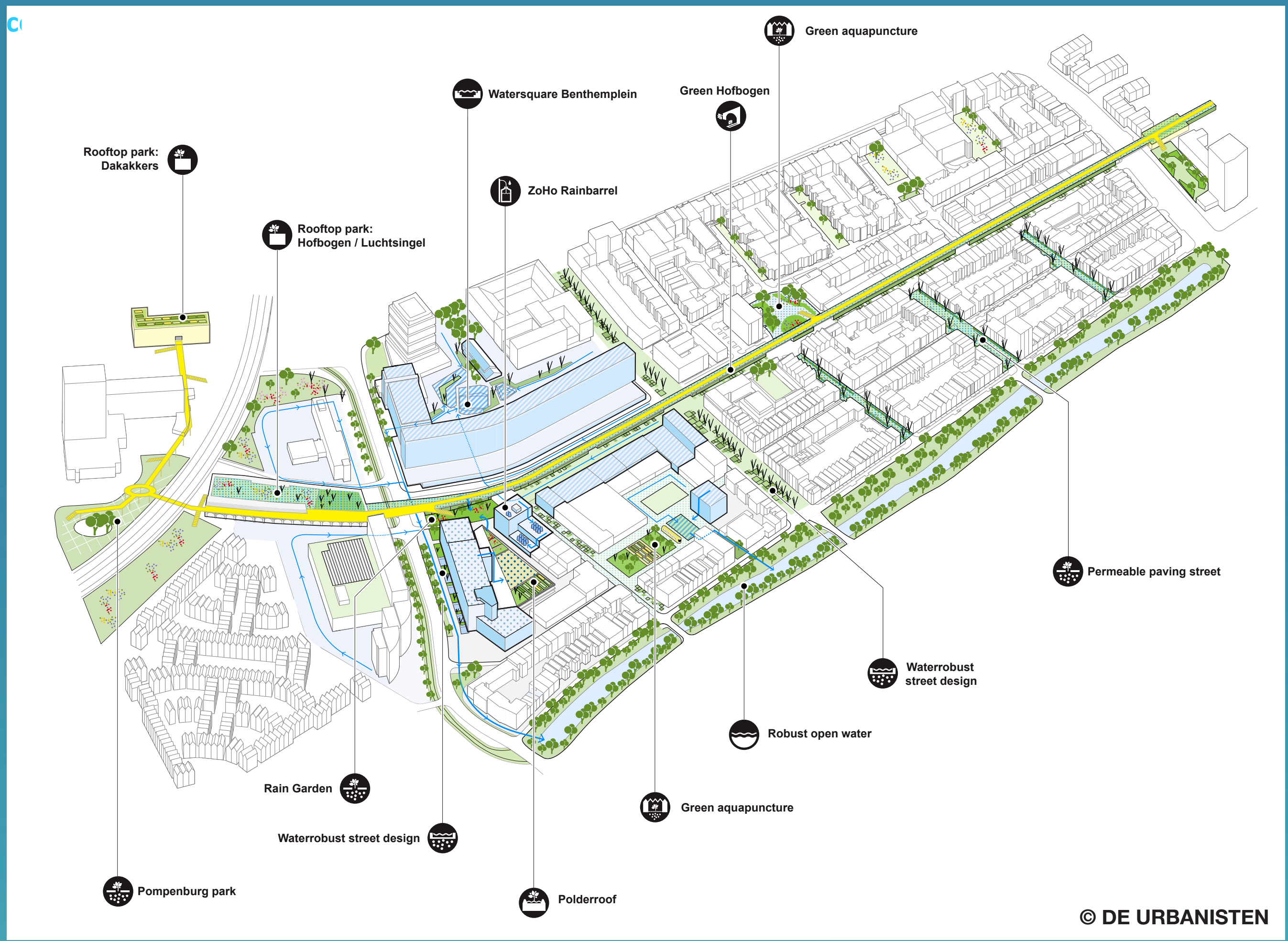
- *Protection*: Protect Rotterdam against flooding, both inside and outside the dykes.
- *Clean Water:* Ensure water quality required by the European framework directive on water to improve the cities' amenity.
- *Attractive City:* Integrate urban planning with water management to solve water problems and enhance the city's attractiveness as a place to live, work and relax.
- *Sewers*: Reorganize stormwater runoff via decentralized innovative solutions that perfectly match the specific area.

The plan for Rotterdam Water City 2030 works in three main areas (Municipality of Rotterdam et al. 2007a):

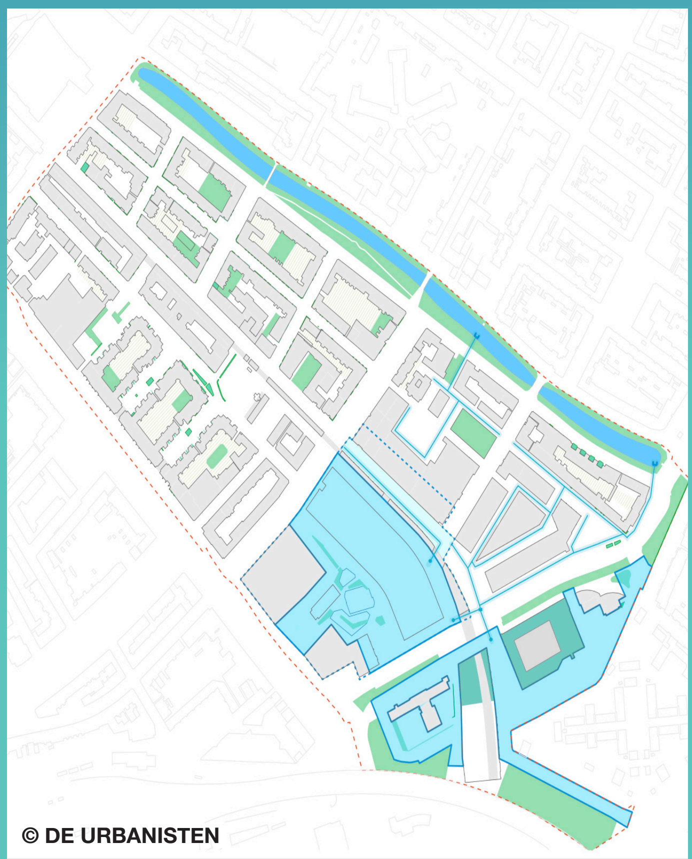
- *River city:* It mainly consists of the area outside the dykes. The city of Rotterdam has a unique waterfront with several dynamic areas and several zones that need to be regenerated and could be used for living or working. The idea is also to improve the use of the river, providing more opportunities for transport.
- *Rotterdam Noord: In the northern area of the city, there are commercial and residential areas where living along the water is very popular. There are several canals and "boezems" (drainage pools) that are used for water storage. For this area, the Waterplan wants to extend them where possible to increase the quality of the urban area.*
- *Rotterdam Zuid:* The area in the south of the river is rich in water since it is the area where the harbour is more developed. In the south there are more possibilities to implement new approaches. The reinforcing of the existing canals with the development of an entirely new network of waterways could develop a completely new innovative connection system.

Figure 9
Maeslantkering Rotterdam Harbor Gate (© InHabitat)

BOX 2 - CLIMATE PROOF ZOMERHOFKWARTIER (ZoHo)



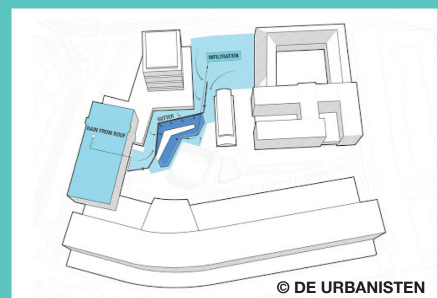
Masterplan of the plaza with the three basins



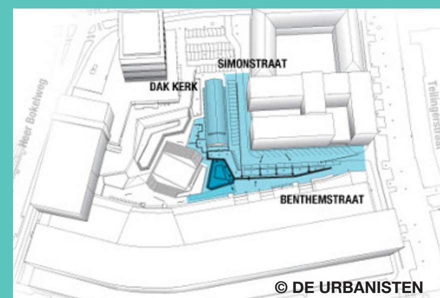
In 2014 the Studio De Urbanisten developed the projects "Climate Proof ZOHO" as a practical application of Waterplan 2 on a district scale. The project identified Zomerhofkwartier (ZoHo) as the urban laboratory in Rotterdam to implement climate measures in combination with the urban transition and its local initiatives (De Urbanisten). ZoHo was chosen because it is in a vulnerable area due to the effects of heavy rainfall and heat stress. The project of Benthemplein was characterized by hard surfaces that now makes place for a structure of more soft and green public spaces that can hold water by infiltration and local storage (De Urbanisten). The project includes Water Square Benthemplein that is already built and ita has a different approach in comparison with the other WSUD tools. The square is composed buy three basins made in concrete that collect the water during the storm.

Render of the new public space profile during a rainy day

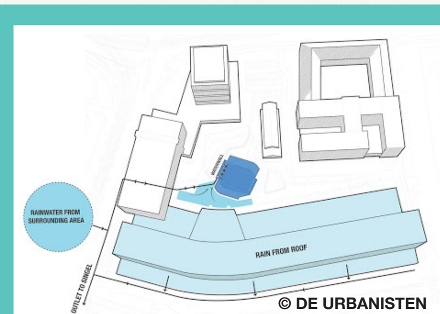
Water Square Benthemplein example



Catchment area of basin 1



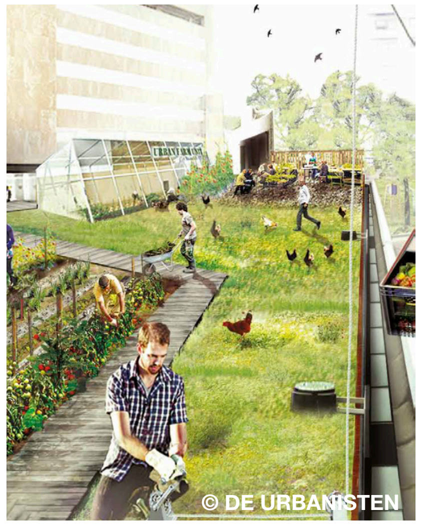
Catchment area of basin 2



Catchment area of basin 3

2.2.3 Tools overview

Polder roof



Rooftop retention

Passive evapotranspiration

The project proposes the transformation of a parking garage into an attractive green roof that stores and reuses rainwater for urban agriculture. It will also become a place for recreation with a good microclimate thanks to passive evaporation.

Living pavement

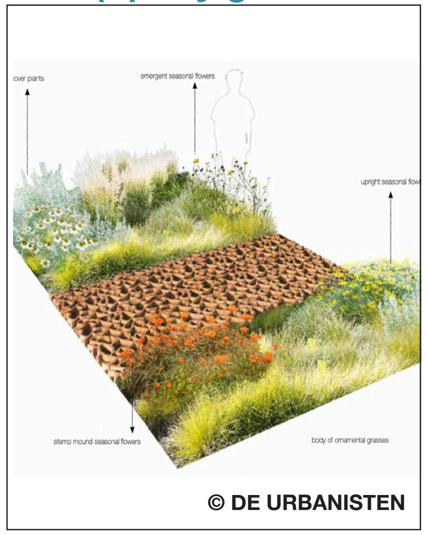
Gravel or sand filters

Permeable paving

Passive evapotranspiration

Living Pavement is an open-tile system that enables spontaneous vegetation in urban public spaces. The gravel substrate permits water filtration and permeability in case of rain.

Rain(A)Way garden



Bio-retention areas

Geo-cellular system

Passive evapotranspiration

This is a new street profile where a new concept of tiles will be tested in the context of a colorful linear rain garden. This kind of permeable paving consists of a geo-cellular system that will contribute to the infiltration capacity.

ZoHo Raingarden

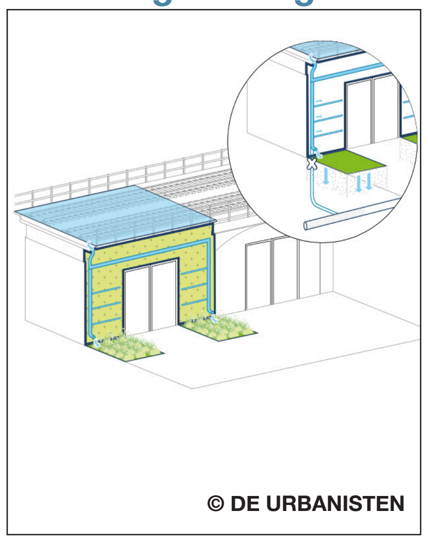
Biotopes

Detention point (dry)

Passive evapotranspiration

This project turns an abundance of hard surfaces and underused parking spaces into an attractive garden that collects rainwater from nearby buildings and public spaces in case of rain. The high quantity of vegetation can create a biotope.

Greening Hofbogen

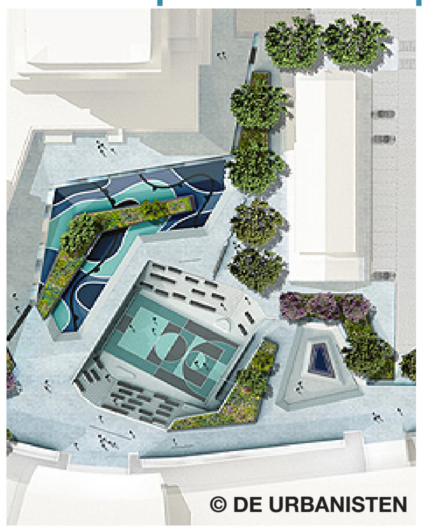


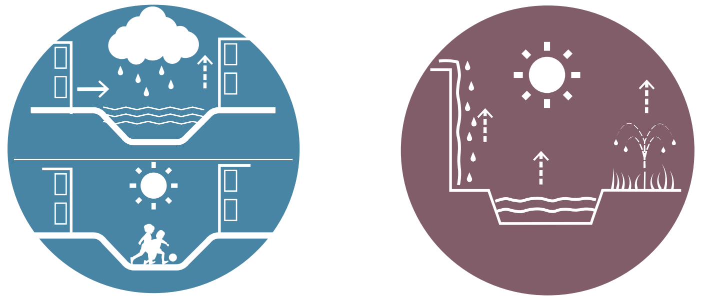
Green facade

Passive evapotranspiration

This tool aims at climate-proofing the monumental structure of the 'Hofpleinlijn'. The intervention on the facade addresses issues like restoring urban ecosystems, edible growth, rainwater reuse and public urban furniture.

Water square Benthemplein





Water square

Active evapotranspiration

The water square combines water storage with the improvement of the quality of urban public space. It also generates opportunities to create environmental quality. When the basins are full, the water creates a nice microclimate.

2.2.4 Criteria application

Water sensitivity

In the Climateproof ZOHO project, the concept is to collect the water by using an impermeable surface to develop a visible water collector, in the projects for the neighborhood, the concept changed thanks to the use of green areas. In the future, the Waterplan intends to increase porous surfaces, so pilot projects like the Polder roof or rain garden will be implemented in ZoHo to minimize the risk of flooding. The polder roof project proposes the transformation of a parking garage into an attractive green roof that stores and reuses rainwater for urban agriculture. With the rain garden hard surfaces and underused parking will turn into an attractive garden that collects rainwater from nearby buildings and public spaces. Interesting is also the introduction of the green facades in the "Hofpleinlijn" station. This tool can collect rainwater from the roof and before draining it into the ground, the water percolates along the facade. In this way, the plants retain the water reducing the quantity that is discharged into the sewers.
The possibility to collect the water during the storm without the opportunity for it to run off into the sewage system is also the basic idea of the Water Square Benthemplein project. The concept of this square is to mix the possibility to develop a dynamic and attractive urban reality with the opportunity to solve the problem of water management during the intense storms that have increased a lot in the past decades.
The square is just the final terminal of a more complicated system that involves the entire surrounding buildings of the block. On rainy days, the water from the roof of the buildings and the surrounding public spaces is collected using specific channels and then directed towards the square. The square is located in one of Rotterdam's areas where there is a higher probability of flooding problems. The 90% of the time, the square is dry and used as a playground area and for relaxation or other conventional public uses. During the other 10% of the time, rainwater is collected in the square. In total, it is possible to collects 1.700 mc of water that is statistically reached every two years (Boer, 2010). At the end of the storm, the water will stay in the square for no more than 36 hours, and then it will be slowly discharged into Rotterdam's sewer systems. Part of the water can also be collected in an underground collector and used for the irrigation system in dry periods.

Figure 10
One of the basin with the water after the storm
(© Rotterdam Centre for Resilient Delta Cities)

Permeability

The possibility to increase permeable surfaces in urban areas it is one of the biggest challenges for cities that want to face climate change and reduce flooding problems. The ZoHo projects want to increase the porous surfaces in a dense urban area that is mainly composed of hard surfaces. It is a significant effort to equip the entire district with these kinds of tools that need to work together, but it is essential to reduce the pressure on the sewer system. This is because the sewer system carries the water to the nearby canal that could overflow during a storm.
On the other hands, he example of Benthemplein is an innovative case in which WSUD tools are implemented without the use of permeable surfaces. Just some parts of the plaza are used as planting elements for trees, flowers, or other kinds of small vegetation that are useful to reduce the heat-island effect. As chapter 1.4.4 said, the WSUD tools are made by permeable surfaces that generally have the aim of filter and clean the water. In this case, the tools like channels, canals, or swales are impermeable and collect the water from the roofs of the buildings or form the public spaces of the neighborhood. The rainwater is then directed in an underground filtering plant called the "water chamber." In this case, water chamber completes the filtration task otherwise done by vegetation and introduces clean water into the square.

Aesthetic benefit

The aesthetic considerations for the ZoHo project are similar to the considerations for Augustenborg. The use of different species of greenery, trees, and flowers gives the possibility to have a continuous change of the landscape during the year. On a rainy day, it is also interesting to see the transformation of the city where the water becomes part of the scene, while generally it is considered just a waste element.

Figure 11
Big stainless-steel gutters that can be elements fit for skaters. (© landscape@urban)

In the traditional water management systems, when the rainwater does not runoff in the sewer system, it is collected in cisterns and underground basins. Different is the case of Benthemplein because because the rainwater basins are visible; they capture the attention of city inhabitants and give new aesthetic value to the public space. Rainwater is transported via large stainless-steel gutters. The gutters are oversized steel elements fit for skateboarders. Two other special features visibly bring stormwater onto the square. They are a water wall and rain well. The rain well is designed as a special beginning to the stainless-steel gutter lifting itself from the ground. This well brings the water from the adjacent building into the gutter. The water wall brings the water from the lowest basin into the deepest one.

Integration in surrounding area

The measurements proposed in Waterplan 2 are the result of different departments and water boards in the city of Rotterdam. The aim is to develop site-appropriate strategies for different parts of the city (Hoyer et al., 2011). For example, the development of the water square, green roofs, and water gardens in ZoHo respond not only to the necessity of water management but also to the need to enhance the attractiveness and cohesiveness of the neighborhoods.
In ZoHo, new green surfaces are essential because several hard surfaces are underused. They could be transformed into WSUD elements, increasing the values of the public space and the buildings around it. The polder roof and rain garden become new community spaces, improving the livability of the area.
Regarding Benthemplein, the plaza is situated in a block with buildings in modern architecture. For this reason, the plaza is well integrated into the context because the irregular geometric figures with sharp edges interact well with the surrounding structures.

Appropriate design

In order to find the best design of the new tools in ZoHo, the development process included an in-depth analysis of the district climate conditions (De Urbanisten). With some workshops, the inhabitants and professionals worked together to define specific strategies and identified the correct measures for the neighborhood. Even for Benthemplein several studies were done to identify the correct position of the square. For example, height measurements were taken, flow-off simulations modelled, and water detention capacities calculated. Once the correct position was identified, some models tried to determine how the water square could look in terms of shape and materials.
Generally, the WSUD tools are made with vegetation and wood material that give a natural feeling to the area. Benthemplein is mainly modern architecture; for this reason, the use of concrete and steel for the construction of artificial swales and canals is probably the correct choice.

Adaptability

The interventions that the city of Rotterdam implemented in ZoHo are an excellent example of adaptability. The previous analysis showm how the water square is used in different weather conditions. 90% of the time, it is dry and can be used for every kind of event that characterized a square. The basins are made to be playground areas while the upper parts are used for socialization and events. During storms, the square adapts and collects all the water that comes from the surrounding areas.

Since this area is located at the mouth of the Rotte river, it is more subject to flooding. For this reason, the combination of the water square with the WSUD tools of the ZoHo projects could be an opportunity to adapt to future climate change challenges. Since the Benthemplein square is an engineered structure, it has a specific capacity. Statistically, the maximum capacity is reached every two years, but in the future, the amount of time between extreme episodes could be shorter. In this case, the combination of the water square and the WSUD tools that will be implemented in ZoHo has the potential to reduce the general water stress in the entire district.

Appropriate usability

A dense urban area characterizes ZoHo. There are no parks, so the space to implement water management tools needs to be found in other places like recreational or conventional spaces.
In Benthemplein, the square was rebuilt to become a rain basin that is used as a playground and recreational space during dry periods. In the other part of the district, several hard surfaces in public spaces will be transformed to become multifunctional areas that manage the water during the storms but otherwise can be used for recreation.

Figure 12
The square during an event when the basin is used as a stage.
(© landscape@urban)

Public involvement

Public involvement was essential for all the projects related to Waterplan 2. Therefore, workshops were held to motivate citizens to participate in the design and planning process.
Before the beginning of the project, Zomerhofkwartier was characterized by years of decline. With the beginning of the new planning process, local entrepreneurs, creative professionals, and neighborhood associations were involved to experiment new ways of development.
For Benthemplein square the students and teachers of the Zadkine college, members of the adjacent church, youth theatre, and inhabitants took part in several meeting. For example, they established that the water should be visible and running over the square (De Urbanisten). At the same time, they were worried about the security of the area. Hence, the planners decided to colour the parts of the square that could be flooded.

Interdisciplinarity

Rotterdam had a high capacity to involve all the stakeholders in the urban transformation that occurred in the municipality. Even during the production of Waterplan 2, the city followed an integrative approach. In the development of the plan, water management planners worked together with urban development planners and landscape architects. Specifically, in the two projects of Climateproof ZOHO and Water Square Benthemplein, the studio De Urbanisten was responsible for the reduction of the urban transformation. De Urbanisten is a renowned international urban design and landscape architecture firm that has experience in interdisciplinary collaboration to identify water solution projects.

2.2.5 Final considerations

Incrementation in water sensitivity

The lack of green surfaces in the Zomerhofkwartier allowed planners to experiments with new kinds of tools and approaches. The necessity to increase the capacity of the neighborhood to retain the water is fundamental in an area that has always suffered from flooding problems.

The ZoHo project aims to introduce several tools in the entire district that, working together, can collect the water and reduce the percentage of it that is discharged into the sewer system. Elements like the rain garden, the polder roof, and the green facades are all able to retain the water, increasing the permeability of the entire water management system.

The idea of the planners to work on the redevelopment of the pavement system is also interesting. The study projects of living pavement and the Rain(A)Way garden (section 2.2.3) are particularly relevant. The first one transforms the sidewalks in permeable paving. The geo-cellular elements of the second solution can retain the water in underground permeable small cells that reduce the runoff speed.

The water square is probably one of the most famous tools that the city of Rotterdam has developed to increase water sensitivity. The high retention capacity of the three basins of the plaza is a relevant defense against the increase in water storm events.

Permeability and evapotranspiration improvements

The combination of all the tools projected for the example of Zomerhofkwartier gives the possibility to significantly increase the evapotranspiration in the district.

Before the development of the project, the neighborhood lacked green areas. The analyses that were done during the development of the project demonstrate not only the risk of flooding but also the increase in heatwaves events (that are another climate change problem).

The implementation of WSUD elements in the area is considered fundamental to face these problems. The introduction of several green areas in places where before there were just impermeable surfaces promotes the passive evapotranspiration process.

In the example of water square Benthemplein, the high percentage of impermeable surfaces cannot promote improvements in natural passive evapotranspiration. An active process is possible when the square is covered by water, but to solve the problem in the other 90% of the time, some water playgrounds were developed. In this way, artificial active evaporation is promoted improving the microclimate's quality.

Aesthetic improvements

The implementation process of WSUD in Zomerhofkwartier permits a requalification in the neighborhood aesthetic perception. The previous parking lots and monotonous impermeable surface with the ZoHo project can be transformed into new green spaces. The change in the urban landscape during the seasons, due to the variety of the vegetation species, is an opportunity to regenerate the district aesthetic.

The approach that the planners had in the project of water square Benthemplein is also interesting. They took advantage of one problem to improve the aesthetic of the neighborhood. During the workshop, the inhabitants were worried about the safety of the area in case of a storm. To solve this issue the developer painted the ground of the basins with some colors to make the unsafe areas during the rainy days immediately visible.

Figure 13
Top view of the square where are visible the colored parts that are unsafe during a storm. (© landscape@urban)

2.3 San Kjeld (Copenhagen)

2.3.1 Background

Copenhagen is the capital of Denmark, with a population of more than 600.000 inhabitants in the municipality and then 2,5 million in the metropolitan region. Copenhagen is part of the Öresund Region together with Malmö in Sweden .

After the Second World War, the city has seen a significant increase in its population. The so-called "Finger Plan," published in 1947, was the planning tool that permitted the management of the new housing investments in the metropolitan region. The plan encourages the creation of new houses and offices along with five linear development areas (the "fingers") with large green spaces between them stretching out from the city center along the regional train routes (Bedrone, 2014). Since 2001, the city of Copenhagen is connected with the Swedish Malmö with the Öresund bridge that permits a rail and vehicle link between the two cities.

2.3.2 From Copenhagen Adaptation Plan 2015 to the climate resilient San Kjeld

As every kind of planning instrument, the plan is the result of a As every kind of urban planning instrument, this plan is the result of a long process (starting in 2009). At the time, the city of Copenhagen hosted the COP 15 (Conference of Parties). The COP "is the decision-making body responsible for monitoring and reviewing the implementation of the United Nations Framework Convention on Climate Change" (WMO, 2020). 197 countries and territories are included in the conference, that has annual meetings to discuss climate change and future international interventions. During the COP 15, the so-called "Copenhagen agreement" was developed. The agreement recognizes "the scientific view that the increase in global temperature should be below 2 degrees Celsius" (United Nations, 2009). After this important event, the city of Copenhagen started the development of the First Climate Actions to prepare for a future with a warmer, wetter climate with an increase in extreme weather events.

On the 2nd of July 2011, the most important flood of the last decades occurred in Copenhagen. In 10 minutes, 20 mm of rain fell and in 2 hours more than 150 mm. The entire sewage system discharged the water into the sea, prompting a temporary increase in the sea level. The water overcame the city protections, and it came back to the urban area, flooding more or less the entire city center. The estimated damages were calculated as 800 millions of euros. This 2011 flooding event is considered a fundamental element in the Copenhagen planning process since it accelerated the production of the Adaptation Plan.

In 2012, the city reached the first important step of the adaptation planning process with the publication of the "Cloudburst Management Plan" (2012). This plan addresses the challenge of floodwater with a holistic approach (Caldarice, 2017). The document aims to redevelop the entire sewage system. This solution is a significant investment that completely deletes the future post-emergency costs in case of extreme weather events. Copenhagen was able to work with water utility on a comprehensive restructuring of the Copenhagen drainage system and direct water to outlets and retention basins.

The Cloudburst Management Plan was designed to manage water in case of extreme events, while the innovative step is the reduction of the "Climate Adaptation Plan" (2015). The final goal of the plan is to promote a Copenhagen carbon neutral by 2025. The document has several innovations that support a complete change in mentality. Firstly, the report does not only talk about water management but takes into consideration all the climate change problems, so also the rising average city temperature that creates a heat-island effect. Secondly, the plan says that "it is not possible - either technically or economically - to protect Copenhagen completely against climate-induced accidents. A whole series of measures can be taken that either prevent the accident, reduce its scale or reduce vulnerability to it" (Caldarice, 2017).

Figure 14
Copenhagen flood in 2011
(© Oppla.eu)

BOX 3 - THE CLIMATE RESILIENT SAN KJELD

© Tredje Natur

One of the most significant projects under development in Copenhagen is the regeneration of San Kjeld project in the Østerbro neighborhood. The project aims to transform Østerbro in the first climate-resilient neighborhood in the world. The project was made by the architecture studio Tredje Natur that designed a radical transformation of the public space to increase the green in the district. New trees will be planted, small urban parks, new green dunes, and new streets pavements are under construction to manage the excessive quantity of water that is discharged in the harbour in case of storm events. The project is ambitious because it covers 105 hectares to reduce by 20% of the areas for the vehicle traffic and use them for the new green spaces.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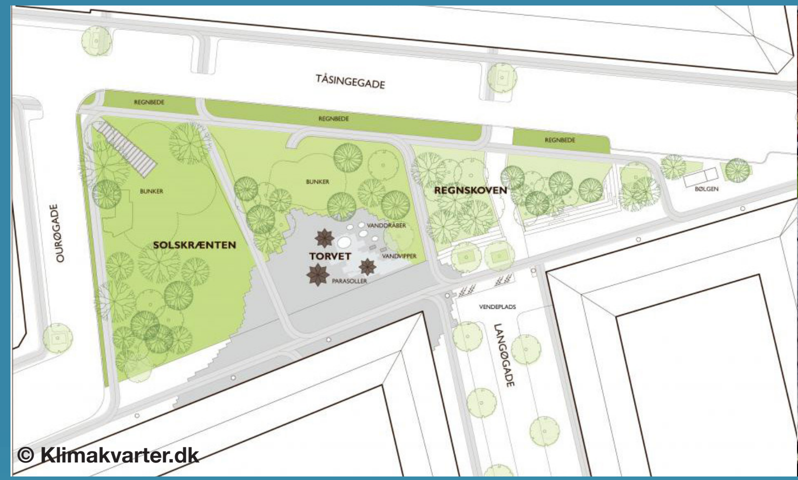

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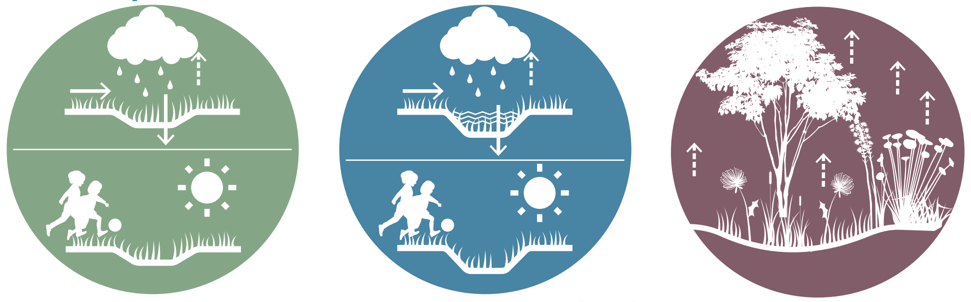
Images explanation

In the big box of the previous page, it is possible to find the masterplan for the entire neighborhood. The two small images show the render of how it suppose to be during a storm a typical recreational space (top) and an ordinary stree.

In the upper box of this page, we can find the masterplan and the final result of Tåsinge Plads. The same happens for Skt. Kjelds Plads in the central box, while the small image on the left explains how it is possible to develop a street using WSUD tools.

2.3.3 Tools overview

Depression area (Tåsinge Plads)

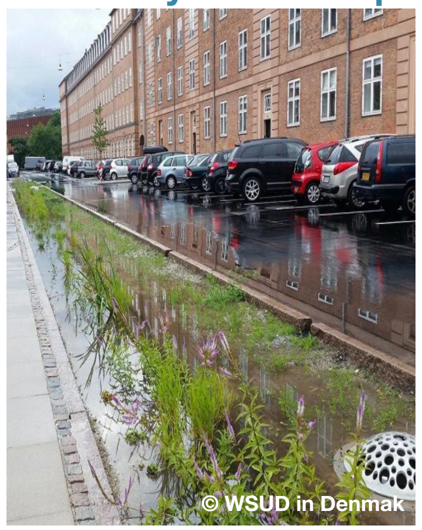


Tåsinge Plads has in its final corner a depression where the water is collected in case of a storm. The high intense vegetation permits passive evaporation that creates a good microclimate in the urban space.

Dry detention points (Tåsinge Plads)

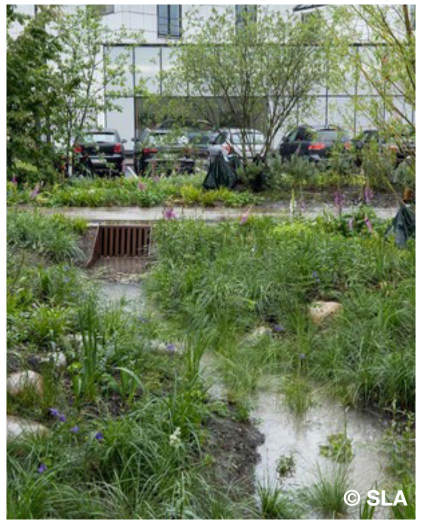
The other parts of the square ar retention areas not deep as the previous one. They are used as recreational spaces but in case of a storm can flood and the vegetation can treats the water.

Linear dry detention point (Tåsinge Plads)



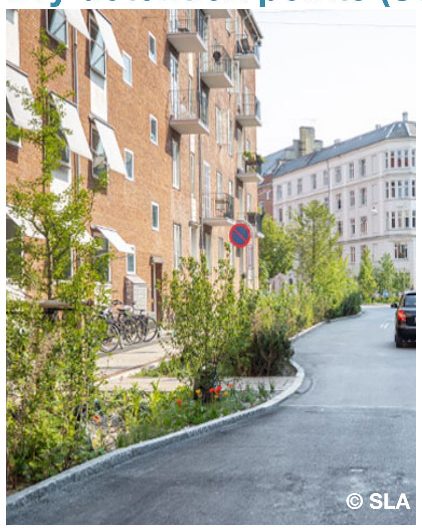
This tool is along the street border of the square. It is generally dry and full of vegetation that permits passive evaporation but in case of a storm can flood.

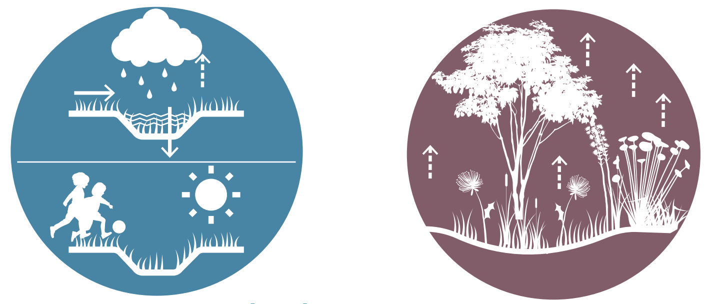
Dry detention points (Sankt Kjelds Plads)



Every corner of the square is full of small depression that can collect the water during the storm. The high quantity of vegetation species promotes passive evaporation and hosts several animals creating biotopes.

Dry detention points (Streets)





The section of the main streets was reorganized reducing the number of parking lots and developing small detection points that can flood if necessary.

2.3.4 Criteria application

Water sensitivity

The projects proposed and under development in Copenhagen are a combination of several WSUD as shown in section 2.3.3. Several pilot projects are already completed and they represent an important example of the criteria application.
The first project is Tåsinge Plads that it is considered the first climate-adapted urban space in Copenhagen. The square is a green oasis, able to capture large volumes of rainwater, but at the same time, it creates a meeting place for the residents of the neighborhood. The public space has a triangular shape. In half of the plaza, there are dunes where the water can infiltrate. In contrast, the other half is a depression with vegetation in which the stormwater is collected and filtered when necessary. The square can collect the water from the surrounding buildings and public surfaces. Altogether, Tåsinge Plads can delay and percolate rainwater from a surrounding area of 4,300 m2.
Another example already constructed is Skt. Kjelds Plads. The square is located in the neighborhood's centre and is the point where all the neighbourhood's streets converge. Before the projects, the cars had a predominant role in this public space that was mainly covered by impermeable surfaces. The project done by SLA Landskabsarkitekter transformed the square into the green heart of the neighborhood. The space for cars was increasingly reduced. Just the central part with a small roundabout is dedicated to traffic, while all the areas close to the building have become small parks, sitting areas, and playgrounds. Every corner of the square is equipped with dry detention point areas that, in case of extreme storms, can play an essential role as a water collector.

Permeability

The possibility of increasing the porous surface is the crucial element of the new climate-resilient San Kjeld. Before the construction of the new WSUD tools, all the public spaces where mainly impermeable, but now greenery is everywhere possible. The sections made for the projects of the new neighborhood (Box 3) are useful to understand how vital this criterion is. More or less 30% of the rainwater is treated on the surface, thanks to the different species of vegetation. When the storm is too intense and the water does not have time to infiltrate in the ground, an efficient system of swales discharges the water in the direction of the harbor.

Aesthetic benefit

The aesthetic benefits are an essential addition in the urban landscape of San Kjeld. Considering Tåsinge Plads, the project improved the quality of the greenery in the square. Before the project, the square was just a big green dune with a few big trees. In the new plaza, the trees are maintained, and several more have been introduced. To give the feeling of a "Danish rainforest," several species of local vegetation and flowers were also introduced.
The same situation can be found in Skt. Kjelds Plads. Before the introduction of WSUD tools, the square was just a unique impermeable surface, while now it has become the landmark of the neighborhood. The high quantity of trees creates the feeling of being in a small urban forest even if the square is still the primary traffic node of the district.
The final elements of the new transformation are the streets. In the last months, the main roads were transformed and became green corridors that connect the different parts of the neighborhood. Several parking areas were removed to leave spaces for new flower beds, green connections along the sidewalks, and small detention points to catch the stormwater. The new street sections increased the aesthetic value of the area. From a former industrial district, San Kjeld has now become a nice place to live and walk.

Integration in surrounding area

The integration with the surrounding area was also taken into consideration in the production of the projects. The wild nature of the "Danish rainforest" is perfectly placed in an urban framework of Tåsinge Plads. The Copenhagen pavements inspire the design of the square. It is a kind of pavement that characterizes the neighborhood and is considered a local symbol. From the exit of the buildings, the sidewalks move to the centre of the square dividing it into several areas.
In Skt. Kjelds Plads the surrounding integration was permitted thanks to a complete redesign of the traffic system. Before the project, all the main neighborhood's streets flowed into the plaza, which consisted mainly of a large roundabout. Closing the square and creating a new urban park was not possible, so the solution was the redesign of the street section that flows into the plaza. The traffic area was reduced with the introduction of more green space to reduce the speed of the cars. With this intervention, it was also

possible to redraw the square, reducing the space for the traffic and creating new green areas. In this case, the integration is not with the buildings and the existing urban landscape, since before greenery was completely absent in the area. The integration is between the new green areas in the square and the green spaces in the streets. Walking into the area, you have the feeling of passing from streets where there is low but dense vegetation to the plaza where there are trees and bushes that create a sort of urban forest. Everything is integrated to create a unique and homogeneous landscape.

Appropriate design

This criterion, in the projects for the new San Kjeld climate-resilient neighborhood, is strictly related to the previous one.
In Tåsinge Plads, the studio that developed the projects took into consideration the climate and the surrounding environment. Since the ground has a slight slope in the sea direction that is located on the east part side of the city, the design of the square takes into consideration this element. The west part is the highest part, where there are the dunes that create a slope facing the sun. From here, the landscape slopes away towards an area at a lower level, where there are the water retention areas.
Regarding Skt. Kjelds Plads, the space is designed using as inspiration elements the characteristic biotopes in Copenhagen, such as Utterslev Mose, Kongelunden, and Amager Fælled. In this way, the plaza has a connection with the typical Danish landscape and defines a distinctive urban nature of Copenhagen in a rational and aesthetic way.
Finally, the design of the streets responds to the necessity of traffic speed reduction. The flower beds and green elements were positioned alternately on the two sides of the road. In this way, the straight and regular road turns into a sinuous course, which prevents cars from going too fast.

Adaptability

The entire project of the new climate-resilient San Kjeld revolves around the criteria of adaptation. Section 2.3.2 explains how the city developed the criteria in its planning tools. The process started already in 2009 but after the flooding event in 2011 it has significantly accelerated. Finally, the last step was the publication of the Adaptation Plan in 2015. As the name says, the main goal is the possibility to adapt. The municipality understands that it is not possible to solve the problem of climate change, but it is necessary to adapt cities and make them able to face extreme weather events. For this reason, the San Kjeld projects implement WSUD tools everywhere possible. In the squares and the streets swales, detention points, biotopes, etc. were developed to catch as much water as possible.

Appropriate usability

The example of Copenhagen is probably one of the most interesting in the world for how WSUD tools were implemented. The flooding event of 2011 shows the fragility of the urban system in the face of climate change. In the criteria's explanation in section 1.5.2, it is written that it is possible to implement the WSUD tool in outdoor recreational and conversational public spaces. This is what the municipality did in Tåsinge Plads and Skt. Kjelds Plads, but it is not enough. Copenhagen is located along the Öresunds Strait, so the ground has a slope that discharges all the rainwater into the sea. During the storm, the water runs along the streets, and the main innovation that the city introduced is the possibility to develop swales and water trenches in a dense urban context. The criterion of usability is exploited to the maximum because every public space becomes a possible place where a WSUD tool can be implemented.

Public involvement

The citizens were involved in the planning process of the new public spaces since the beginning of 2012. Several meetings, workshops, and project groups helped the planners to find the most suitable design interventions. The WSUD tool can be integrated into every kind of urban space, but proper public involvement is fundamental in giving knowledge and ownership of the project. In this way, they feel reassured about the future inconveniences caused by construction. The approach that the municipality is using for the Tåsingegade street is particularly interesting. Nowadays it is an impermeable street with parking lots on both sides. In the future, it will fulfil an essential role for the water management of the area. The road runs from west to east, so the water can run off in the direction of the sea without any obstacles. This could be dangerous, so it is essential to equip the street with WSUD tools. Since Tåsingegade is a common private road, a Tåsingegade association was created to involve the citizens in all the decisions.

Interdisciplinarity

The success of these kinds of projects is, for sure, the result of a heterogeneous working team. Engineers, architects, and urban planners have worked together since the first steps of the development of the adaptation plan.
Once the municipality moved from the planning process to the project's development, this interdisciplinarity was maintained inside the studios. Like the case of De Urbanisten in Rotterdam, the studios SLA Landskabsarkitekter and Tredje Natur are renowned international landscape architecture firms. Their team are comprised not only urban planners and architects, but also engineers. During the project's development, experts in other subjects like geologists, botanists, etc. have always been involved in finding the best intervention for the study area. In Copenhagen, this is visible in the concept of the projects were the typical "Danish rainforest," and the most important Copenhagen biotopes were implemented in the new Tåsinge Plads and Skt. Kjelds Plads.

2.3.5 Final considerations

Incrementation in water sensitivity
The need to make the district of San Kjeld more resilient was fundamental after the big flood of 2011. In the neighborhood there were just a few green areas that were not sufficient to absorb a sufficient amount of water to protect the area. Moreover, the high percentage of impermeable surfaces promote a high and fast runoff that the sewer system is not able to manage.
All these considerations pushed the municipality of Copenhagen to introduce WSUD in the public spaces of the city using San Kjeld as a study area. The concept of the project is really simple, the introduction of dry detention points everywhere it is possible. Section 2.3.3 shows how planners design these tools to adapt them to every kind of public space. Arial elements were developed in the center of Tåsinge Plads and Skt. Kjelds Plads. At the border of Tåsinge Plads or along the streets that are connected to Skt. Kjelds Plads, the solution was found developing linear tools that can collect the water that comes from the asphalt.
The analyses that were done in the previous sections of chapter 2 explain how the tools of green roofs and green facades are important in the capacity to retain the rainwater. Unfortunately, since the district is mainly composed of historic buildings, it was not possible to introduce these elements. Despite this, the introduction of WSUD tools into the public space already retains 30% of water.

Permeability and evapotranspiration improvements
The introduction of several types of dry detention points in the entire district gave not only the possibility to retain the water, but also the possibility to increase the permeability and the evapotranspiration process.
Before the development of the projects, the public spaces were just parking lots or big impermeable sidewalks. The involvement of the citizens in the planning process permits them to find agreements reducing the parking areas to introduce permeable green surfaces. More permeability means a slow runoff but also more evapotranspiration. In this way, part of the water comes back in the atmosphere improving also the microclimate of the area.

Aesthetic improvements
The aesthetic is one of the milestones of WSUD. The cities that implement water management tools in their public spaces always have improvements in the quality of the urban landscape. The case study of San Kjeld is interesting in the introduction of the typical Danish biotopes in the urban landscape. These new green areas introduce a dynamic landscape. The streets are transformed into a nice place to walk during the free time while the square became small parks where the inhabitants have the feeling to be in a traditional forest.

Redevelopment of the whole public spaces
Another interesting positive aspect is the capacity of the city to redevelop the system of public spaces. The reason for this is likely in the adapting capacity that the city had after the big flood in 2011. The event caused damage estimated at millions of euros, so the municipality and all the stakeholders understood that it was necessary to start a virtuous process and change the mentality in which the entire city was planned. Every kind of space was redeveloped to create an efficient system of water management.

The implementation process of some other projects in San Kjeld is still going on. Until now there are no published data that can explain possible problems or particular dynamic between the citizens and the stakeholder, like in the previous two projects analyses. A more in deep investigation should be necessary in order to know more about public involvement, through interviews with the municipality or the planners that are developing the projects.

2.4 Learning outcomes

In this final section of the second chapter there are all the elements This final discussion will answer the first sub-question highlighting the key learning outcomes that came out from the analysis of the previous three projects. The question is:
Considering the design, planning, and public participation aspects, what can be learned from relevant European examples that have implemented WSUD?

The outcomes of the analysis can be divided in the following points.

High retain water capacity
The first outcome is the capacity of the system to retain a high In the case of Augustenborg, the retantion water capacity can reach even 70% of all rainwater that falls onto the site. This percentage is high for a neighborhood that, before the intervention, had several flooding problems. This retention capacity demonstrates the real benefits of the implementation of natural elements able to manage the stormwater into the cities that is one of the main goals of WSUD explained in chapter one. For example, the WSUD system was designed for a 1 in 15-year event, but during a major flood in 2007 (which equated to a 1 in 50 years event), the system was resilient, and Augustenborg fared much better than other neighborhoods in Malmö.
In Augustenborg it was probably easier to find the space for the implementation of WSUD tools. The reason is that the neighborhood was built taking into consideration the need for public space and green areas. A dense urban structure characterizes Copenhagen, so there is less space for new green. For this reason, the system of the new WSUD tools is able to catch around 30% of the rainwater. This percentage is anyway high considering the big damages of the flood in 2011.
Regarding the example of Rotterdam, this kind of data is not available. Still, considering the urban structure of the neighborhood, the percentage of retained waster is similar to the Copenhagen project.

Green roof and green facades role
Another learning element is the importance of green roofs and green facades. They are often used to reduce heat-islands in the cities, to enhance biodiversity, to reduce noise, etc., but they also have an essential role in reducing the runoff. If well designed, they can play an important role in responding to the challenges of climate change. In the example of Augustenborg, the plants and substrate alleviate the pressure on the city's drainage system by absorbing more than 50% of the rainwater. In the polder roof in ZoHo, the water is also collected to be used again in the rooftop agriculture. In this way, the green roof does not only have an aesthetic and water retain function, but it also became a social and recreational element.
These green elements can improve the visual amenity of the urban areas integrating stormwater management elements into the landscape, characteristic that in section 1.4.1 are considered essential for WSUD.

Water treatment ability
Even the water treatment ability is another important goal of WSUD. With the conventional stormwater management, the high run off on the impermeable surfaces it is the main cause of water pollution. As explained in section 1.2, the water pollution has negative impacts on the groundwater quality, water supplies, the qualitative and quantitative state of receiving rivers (Hoyer et al., 2011).
With WSUD that increase the permeable surface the water can be cleaned. In all the three European examples, the detention points distributed in the public spaces are equipped with several species of vegetation that can filtered the stormwater before infiltrating it into the ground. Some of this detention point constitute also biotopes that improve the aesthetic values and the biodiversity of the area.

Citizen involvement
The key element for the good outcomes of the project is citizen participation. The theory explained that the lack of knowledge, acceptance, and awareness is something that slows down the implementation of the WSUD. The inhabitants need to be conscious of the advantages of a sustainable water management approach. WSUD has also social and educational values because it wants to bring the citizens closer to nature by improving the aesthetic quality of the public spaces.
For example, the relationship problems between the inhabitants in Augustenborg created difficulties in the implementation process but despite these problems, their involvement was essential. The possibility to have a voice in the Ekostaden project development increase the awareness of the people about the importance of the WSUD tools.
The examples of Rotterdam and Copenhagen are probably the best case-study regarding citizen participation. In these projects, the inhabitants were not only involved to explain to them the importance of the WSUD tools, but they become an active part of the project's development. Some solutions that were implemented could not be possible without the participation of the citizen.

Chapter 3

Case study

3.1 Backgroung

Heidelberg is a university town in the German state of Baden-Württemberg. It has a population of around 160.000 where a quarter of them are students. The city is part of the densely populated Rhine-Neckar Metropolitan Region.
In the 19th century, the construction of the railway connection promoted tourism that became an important element for economic growth. With the second industrial revolution, a significant urban development started, and the inhabitants quadrupled to 85.000. Numerous modern industries were built together with the tramway and the funicular.
During the first half of the 20th century, Heidelberg continued to grow and during the Second World War, the city remained mostly intact. After the war, construction was started on the Patrick Henry Village, a US camp for soldiers that hosted the largest American communities outside North America. In this village is now under development the project of PHVision that is part of IBA Heidelberg, an international architecture exhibition that wants to show innovation in the field of architecture, urban planning, and urban design.

3.2 History of the Patrick Henry Village site

The Patrick Henry Village (PHV) is a housing area situated in the southern areas of Heidelberg. The Village was built between 1952 and 1955 to host the soldiers that worked in the surrounding military areas and their families. At its most populated period there were 16.000 Americans. The area is located in between the municipality of Heidelberg, Eppelheim, and Schwetzingen. There is countryside along the north and west border, while to the south it borders with the federal road B 535 and to the east with the highway A5.
The area covers 97.2 hectares, roughly the same size as Heidelberg's Old Town. The site contains around 1500 housing units but in its final state, there were also large numbers of educational, recreational (shops, gym, theatre, bowling alley, etc.), and public facilities.
In 2002, the US Army proposed a plan to extend the housing area. The idea was to develop a shopping mall in the south of the site and enlarge the housing area until the closest villages. Due to the financing problems and some protests from farmers, the expansion project was canceled. Another problem was the construction of fences in 2003 as a consequence of the 9-11 terrorist attacks in New York. Before this event, the village was open so the citizens of the surrounding urban areas could visit it and use the open facilities and services. With the construction of the protections, only the people with a special ID could enter in the PHV area.
The military use of the area ended in 2013 after all soldiers were moved to the new headquarters of the United States European Command in Wiesbaden. After the decommissioning, the area was used as a refugee center during the refugee crisis that was taking place in that period. In the PHV area, 4000 asylum seekers were hosted.
In 2013 in the municipality of Heidelberg started the Internationale Bauausstellung (IBA, translated as International Building Exhibition), a special German tool for urban planning and architecture to show new concepts in terms of social, cultural and ecological ideas. The goal of IBA Heidelberg, which is taking place between 2013 and 2022, is to focus the attention on the current social changes and understand them in the urban development and architectural dimensions.

Figure 15
The Patrick Henry Village (© KCAP)

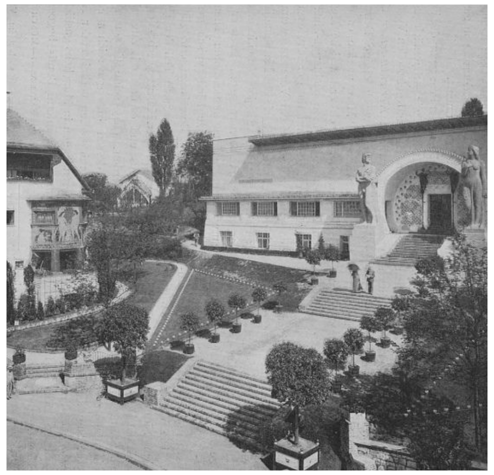


Figure 16
1901 Mathildenhohe
(© Internationale Bauausstellung)

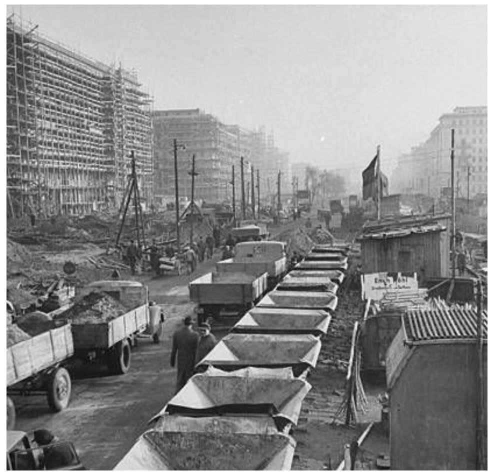


Figure 17
1952 Stalinallee
(© Internationale Bauausstellung)

Figure 18
1957 Interbau
(© Internationale Bauausstellung)

3.3 IBA, Internationale Bauausstellung

Internationale Bauausstellung (IBA), International Building Exhibitions, are a special format for urban and regional development. The IBAs bring the attentions regarding the current planning issues into the national and international discussions. Each international exhibition represented a fundamental step in the historic, social, and political evolution of the areas involved in the transformation. The IBAs are characterized by the limited time frame and the concentration of funds and public attention on the predefined period.
The first IBA was held in 1901 when the hilltop area at Mathildenhöhe (Darmstadt) was developed. Two of the most famous IBAs are the IBA Stalinallee in 1952 and IBA Interbau 1957 in Berlin. The first occurred in the Russian part of the city to show the new ideal of social architecture. The second one occurred in West Berlin where the American tried to find an alternative to Stalinallee socialist model.
The first exhibition in which architects and planners introduced the environmental aspects was the 1999 IBA 'Emscher Park' that regenerated the German industrial area of the Ruhr. The project took as its goal the development of strategies to adapt the area, focusing on the redevelopment of industrial sites into cultural and touristic use.
The case of IBA Fürst-Pückler-Land in 2010 was similar. Lower Lausitz region, south of Berlin, was the main coal extraction area in the GDR. In this case, it was not an architecture exposition but this IBA in 2010 become the largest landscape construction site in Europe. The coal extraction area became lakes and several navigable canals were built to connect the water landscape for recreation.

3.4 IBA Heidelberg

IBA Heidelberg is one of the three current IBAs. This international exposition is taking place in the ten years between 2012 and 2022 with the aim to promote new innovative projects in the city related to the topic of a knowledge society. With the motto Wissen | schafft | Stadt (Knowledge | Based | Urbanism) the city of Heidelberg is trying to answer the question: How does the European city need to transform itself to meet the demands of tomorrow's knowledge society? Heidelberg is considered a suitable experimental area since, both the city and the university have an international standing. The IBA wants to face the conflicts between preservation and renewal to develop the new idea of the European knowledge city of tomorrow.
The projects that will be proposed for the IBA include every kind

of research and educational institution like universities, schools, daycare centers, but also student accommodation, parks, and public spaces. Until 2022, the projects for the new city of knowledge that will be proposed should be divided into five key thematic focuses. Each thematic focus is related to a specific question that the projects should try to answer. The themes with the related question are listed below:

- Science: How must scientific institutions be designed to be drivers of urban development?
- Knowledge space: How can educational and cultural spaces shape identity and inclusion in neighborhoods?
- Networks: How is the European City changing as a result of digitalization and what are the implications for mobility and the design of public spaces?
- Urban metabolism: How can processes around energy, food and water be designed in a sustainable cycle?
- Coproduction: How do we design participation processes in urban planning that involve all relevant stakeholders and use their expertise in order to create ambitious architectures and neighborhoods?

Until now the projects presented for the first thematic are new scientific areas (like Campus Bergheim) and multifunctional spaces (like Heidelberg convention centre). For the knowledge space, there are proposals for the construction of new schools, but the most interesting project is the renovation of the so-called house of youth. This building contributes to the integration of people across age groups with diverse educational biographies and from various city districts. Regarding the network thematic, the aim is to increase pedestrian and cycling connections. The construction of the new Neckar cycle and footbridge that aims to increase the connection between the different scientific and research sites in Heidelberg. In urban metabolism interesting is the development of the agricultural park in the south of Heidelberg. In this park, the landscape can be experienced as a place of education with a mix of food production, recreation, and nature conservation. The project of PHVision that is analysed in this chapter is part of the fifth theme, coproduction. At the same time, the project proposed by Ramboll Studio Dreiseitl for the outdoor spaces of PHVision is included in the urban metabolism since it wants to develop a new neighborhood where energy, food, and water are design promoting a sustainable cycle.

Figure 19
1984/87 IBA Berlin. Schlesisches Tor
(© Internationale Bauausstellung)

Figure 20
1999 IBA Emscher Park
(© Internationale Bauausstellung)

Figure 21
2010 IBA Fürst-Pückler-Land
(© Internationale Bauausstellung)

3.5 PHVision (general overview)

3.5.1 The process

PHVision is the only project that is part of the fifth theme, coproduction. This project aims to develop an exemplary urban design to demonstrate how it can be the "knowledge city of tomorrow".
With an area of more or less 100 hectares, the project area of the Patrick Henry Village (PHV) is almost as large as Heidelberg's old town. The process for the development of the new district is long and involves all the stakeholders like experts, investors, planners, etc. The final result of this long process will be the development of the so-called "dynamic masterplan", that it is still in a draft phase. The masterplan takes into consideration five specific study field that are:

- Architecture typology
- Programmatic profiling and usage mix
- Productive urban landscape
- Mobility
- Digital city

During the development of the masterplan, several workshops and seminars were organized in order to improve the participation of the citizens and all the stakeholders. The masterplan is under elaboration by the studio "KSAP Architects & Planners" in partnership with:

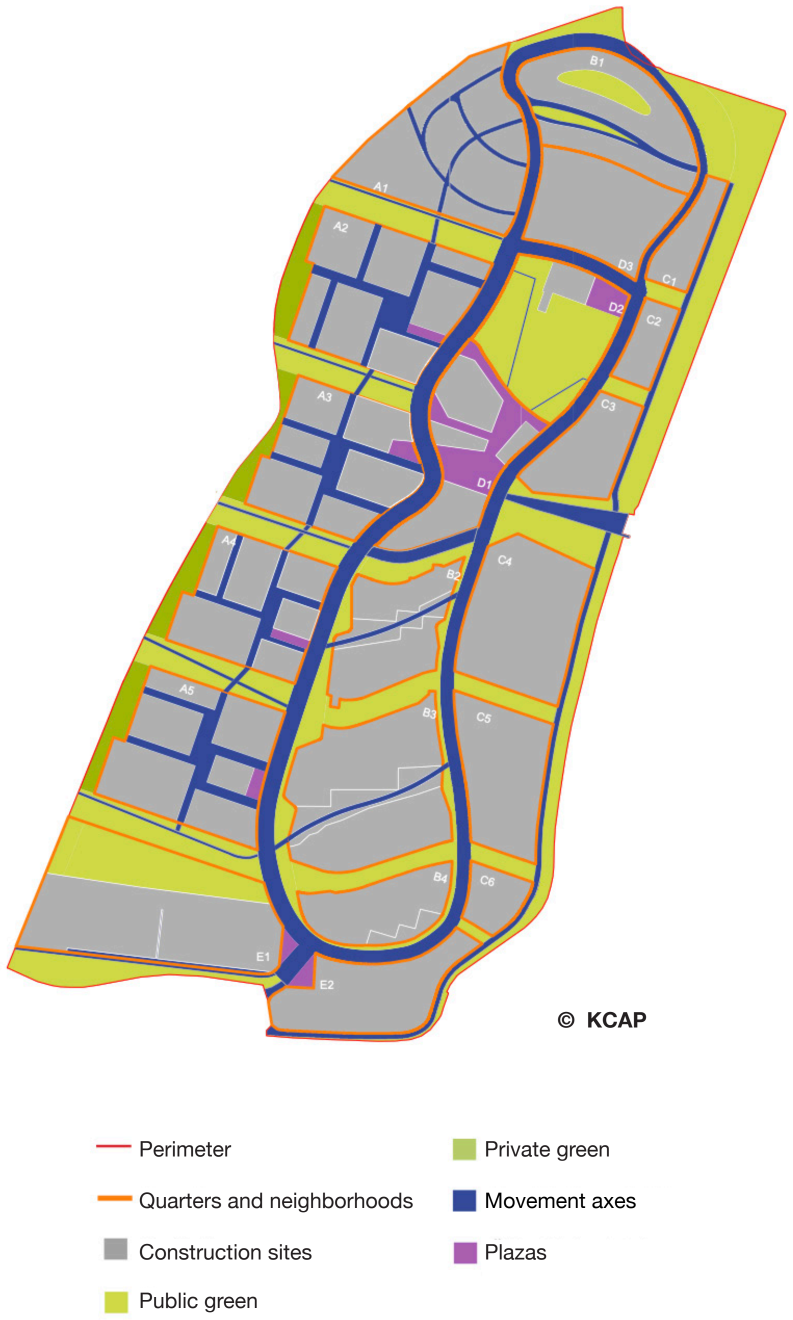
- "Bogevischs buero" (architecture typology)
- "InitialDesign" and "Arup" (programmatic profiling and usage mix)
- "Ramboll Studio Dreiseitl" and "Frauenhofe ISE" (productive urban landscape)
- "Urban Standards" and "Buero happold" (mobility)
- "AIT" (Digital city)

The outcomes are interactions between planning tools, processes, and participants. The result is a strategic document with the fixed specific goal of developing an innovative district, but with flexible regulation. A group of experts will constantly guide the development of this planning tool because the masterplan is a process-oriented planning tool. This means that the document is without a fixed final result, but it will be characterized by a continuous change. The structure of the district and the general land use are fixed while the building design and organization can change.

PHVision masterplan © KCAP

3.5.2 The masterplan for PHVision

The masterplan is based on green spaces and high infrastructure connections. The leading concept at the base of the masterplan is to define general development rules (framework) of the new district. The following map shows the spatial organization of the project area. The areas marked in blue are the mobility axes of the district such as the “Parkway” (a primary loop street that connects the different areas within the redevelopment), and the secondary streets that connect the different blocks with the parkway. The green represents the natural elements like the central park and the green fingers that wedging the area from west to east. The grey represents the areas in which it will be possible to build.



District organization

This area is localized in the western part of the districts. It is composed of new buildings positioned in a privileged area in between the historical buildings and the green countryside. In these new blocks, there will be a mixed-use area where residential buildings are integrated with educational, social, and commercial areas.

Zones

“Area A: Life and Learning” (West area):

This area is localized in the western part of the districts. The band is composed of new buildings positioned in a privileged area in between the historical buildings and the green countryside. In these new blocks, there will be a mixed-use area where residential buildings are integrated with educational, social, and commercial areas.

“Area C: Develop and produce” (Band East):

The center, with the buildings of the 1950s, has shaped the image of the PHV. This area will become the real heart of the new district. With the intervention of retrofitting and expansion, the existing buildings can become the place for a mixed-use area. The idea of the masterplan is to regenerate the buildings in order to promote the experiment of new individual and collective forms of living.

“Area C: Develop and produce” (East area):

The workplaces will be concentrated in the eastern part of the new district along the highway. This part of PHV is mainly composed of large-scale building blocks with several uses. In this case the rule of mixed uses will also be followed. The area can be the place for universities, start-ups, co-working areas, urban manufacturers, industry 4.0, and digitalized logistics.

Quarters and neighborhoods

The structure subdivision in quarters and neighborhoods enables the development of different identities for each area and promotes a sense of belonging. The quarters are defined by mixing different typologies, densities, open spaces, and urban profiles.

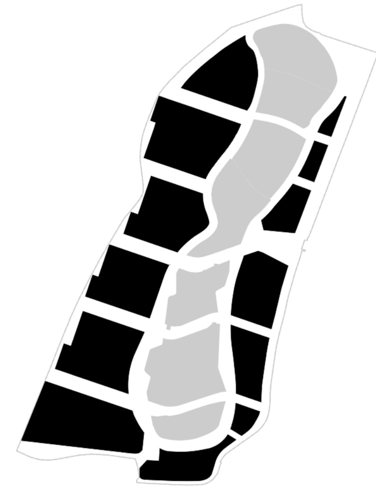


Figure 22
Inside out concept
(© KCAP)

Figure 23
Zones distribution
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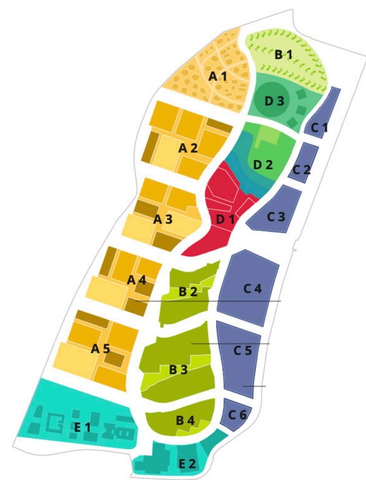


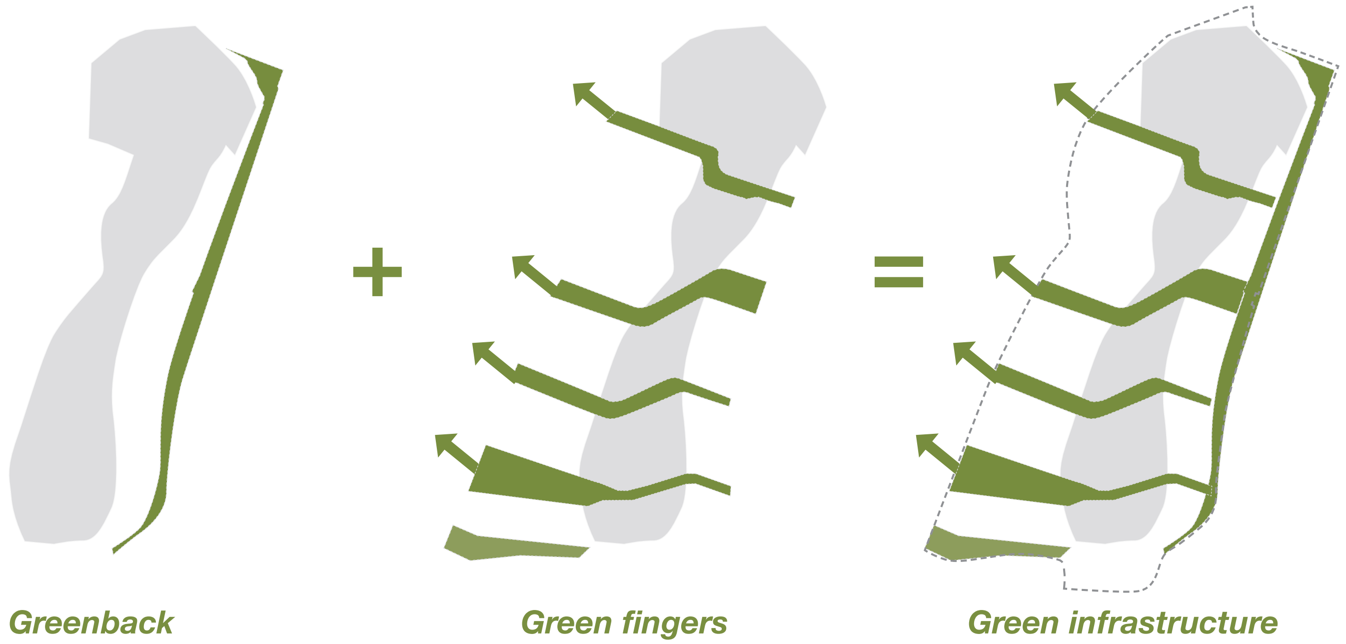
Figure 24
Quarters and neighborhoods
(© KCAP)

3.6 PHVision (green and blue elements)

3.6.1 Overview

The green and blue infrastructure are the milestones for the climate adaptation strategy of PHVision. The natural elements have multiple uses like water management and microclimate improvement. At the same time, nature also means quality of life, health, relaxation, and exercise, but also diversity of species and biotopes. It is understandable that, in this project, nature is not only an essential element for WSUD but it has also a social value demonstrated by the presence of several urban and community gardens.
In this master thesis the attention will be focused on the analysis of the elements that are fundamental for the implementation of WSUD tools in PHVision. The social aspects of nature are not considered in this document.

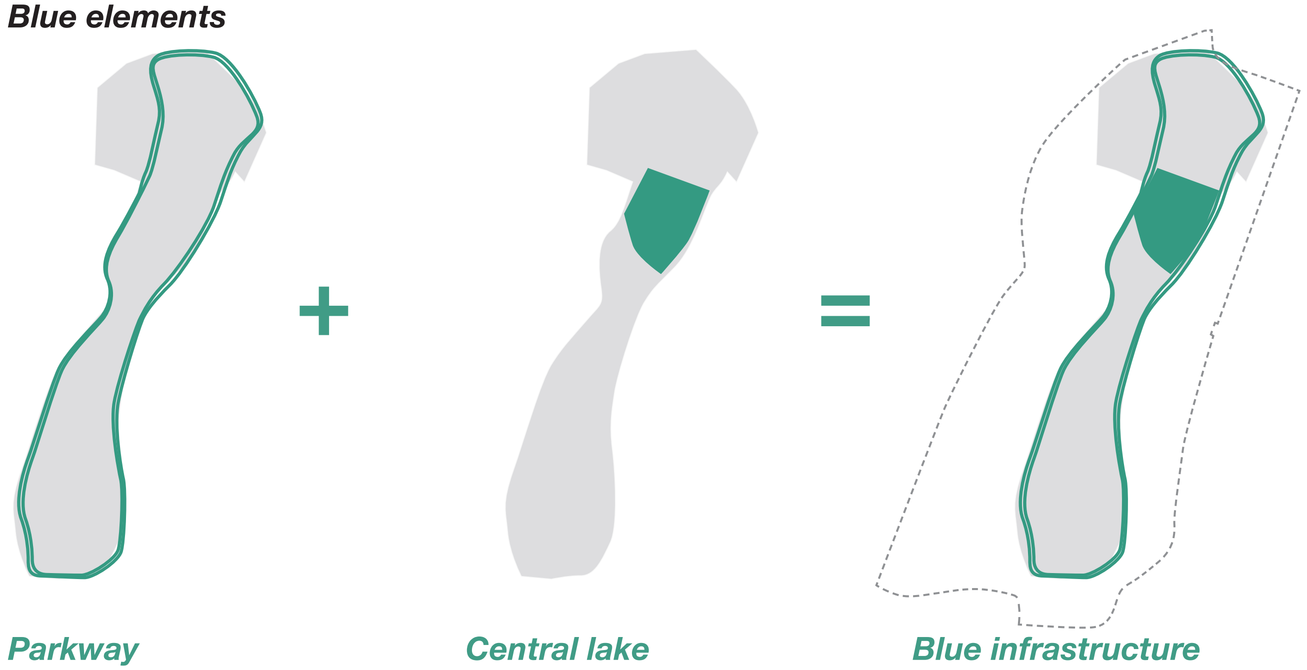
Green elements



The green structure is composed of a combination of two elements. The green structure is a combination of two elements. The first is the so-called “greenback”, a north-south element. Attached to this natural structure there are several “green fingers” that are an east-west connection, representing the secondary element.
The greenback runs along the highway and it is composed of artificial green walls and high density of trees. The reason for this choice is the necessity to protect the district from the air and sound pollution of the highway.

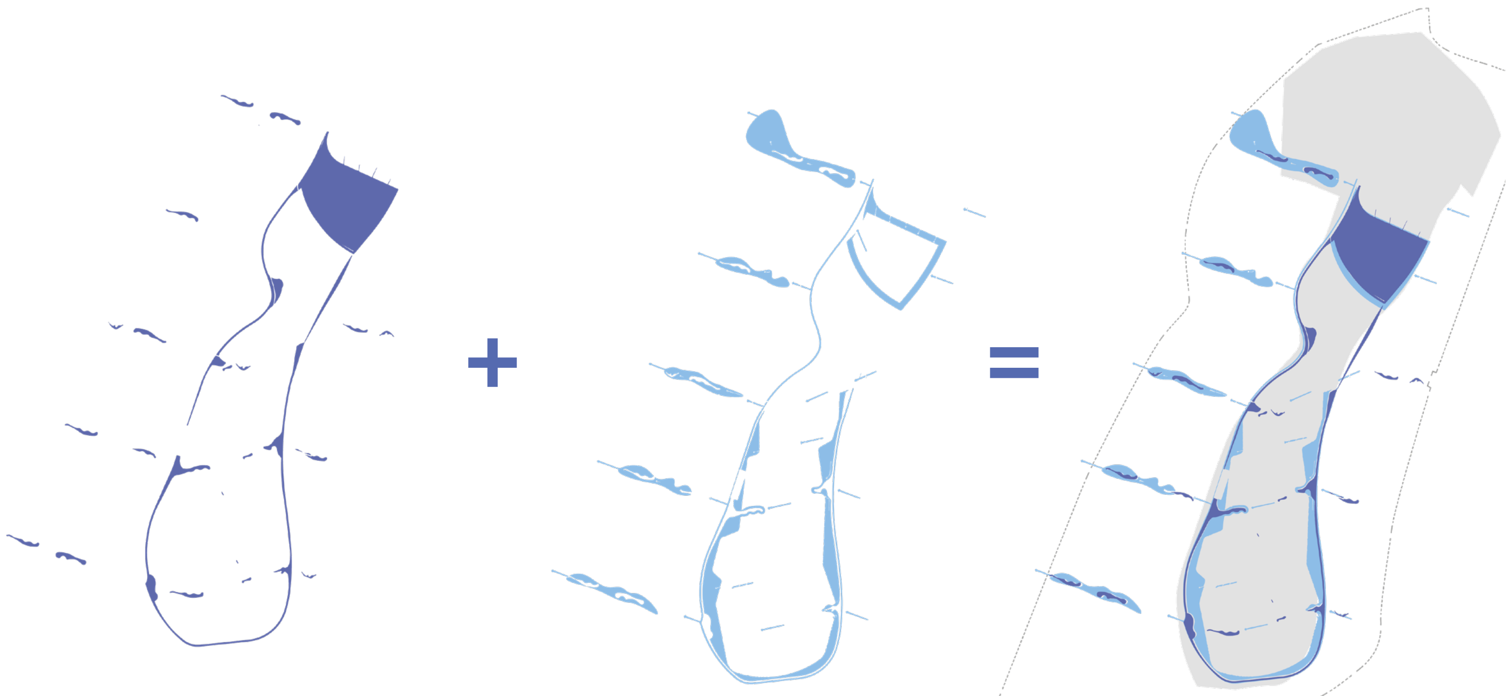
The green fingers are natural elements that cut the district from east to west. They have the role to collect the water that comes from the different blocks.
The motivation of this particular organization of the green infrastructure can be found in the orographic characteristics of the surrounding. On the east part of the site, there are some hills. During the night the fresh air comes down from the hills heading west. For this reason, the green fingers need to be large and have an east-west orientation because they do not have to block the airflow.
The green elements represent also an ecological corridor for the animals. Several species of vegetation, working together with the water collected from the blocks, developed biotopes that improve the quality of the urban landscape.

Blue elements



The blue structure is composed by the “Parkway” and the central lake. The Parkway is the loop road that represents the main car and public transport connection to the district. It also has a relevant role for the blue infrastructure since the water that comes from the green finger is collected in the swales, trenches, and canals situated along the street. From the Parkway, the water is slowly transported into the central lake.
The lake is the heart of the district. It has the role to collect the water coming from the surroundings and to promote a nice environment as an identity element for PHVision.
In the site, there is an interesting geological structure. Since the area is close to the Neckar river, the ground is mainly composed of gravel and sand which allow a natural filtration of the water. In addition,

the aquifer is 10 meters deep, characteristic that permits to protect groundwater from pollutants.
As image the scheme below shows, the water system is projected to face possible heavy rain due to climate change. The green elements permit to make the district like a sponge. There are some areas where there is the water for the entire year and there are other areas already projected to flood in case of intense water events.

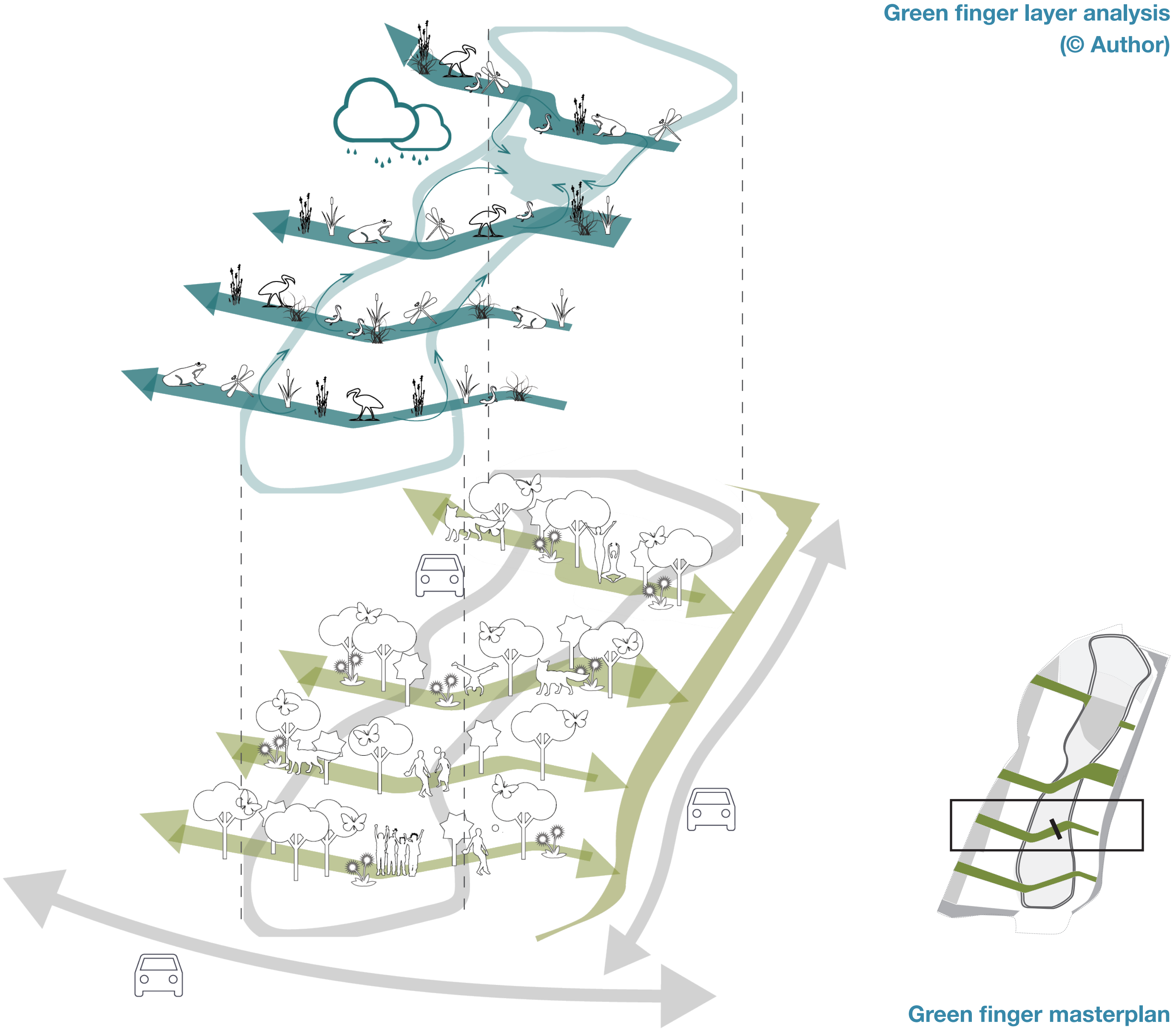


Permanent water *Flood areas* *Sponge district*

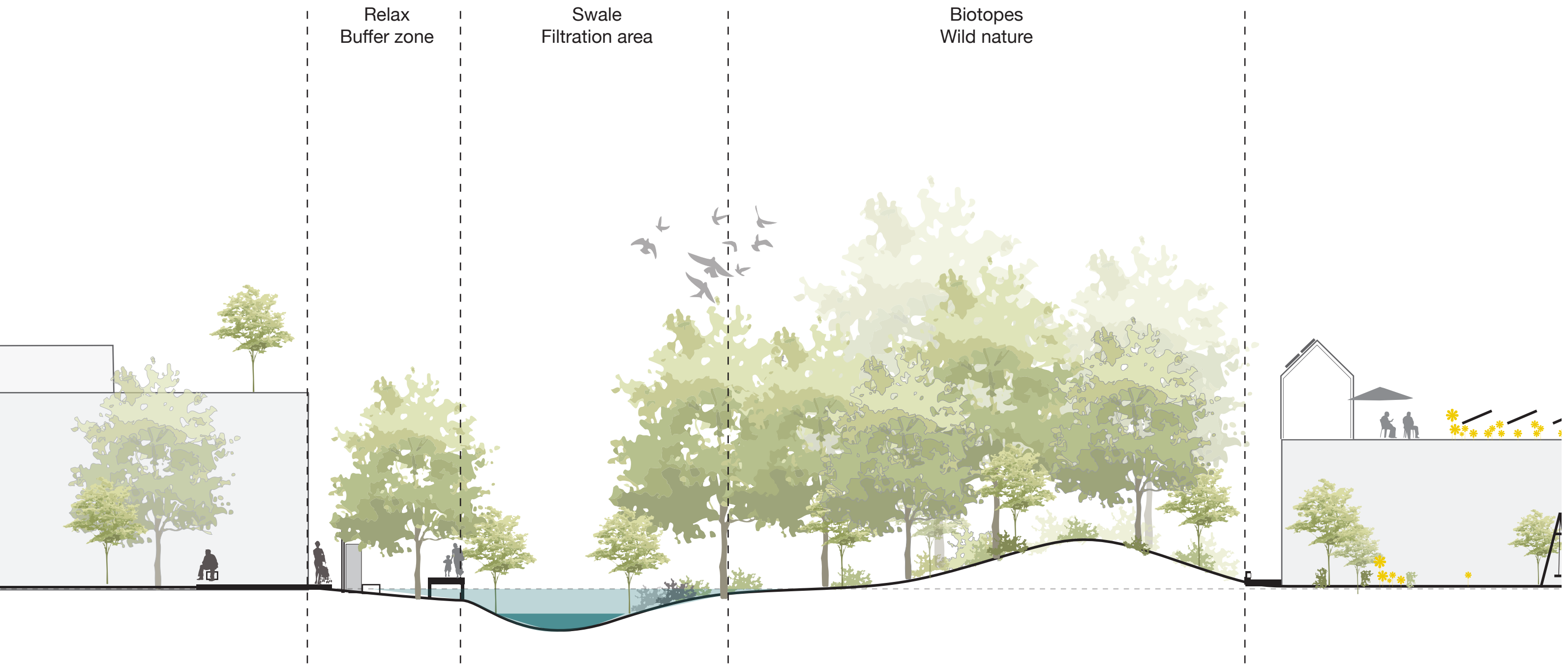
3.6.2 Green fingers

The fingers are fundamental elements to allow nature to enter the district. The green wedges penetrate in the project area, promoting new aesthetic value in PHV. The green fingers are composed of wild nature that hosts different biotopes and several species of animals. The new ecological corridors are essential for water management. The WSUD tools that will be implemented (swales, trenches, and canals) protect the buildings from stormwater thanks to their high retention capacity.
The air coming from the hills in the east of the district combined with the evaporation process promoted by 3000 new trees, will help to regulate the microclimate.
During sunny days, the fingers can be playground areas and places to spend the free time. The swales and all the green elements around are projected to be a learning area. In this way, the fingers are not only a water management element, but with a correct communication system can improve the awareness of the inhabitants on the importance that the water and nature have in the district.

Green finger layer analysis
(© Author)



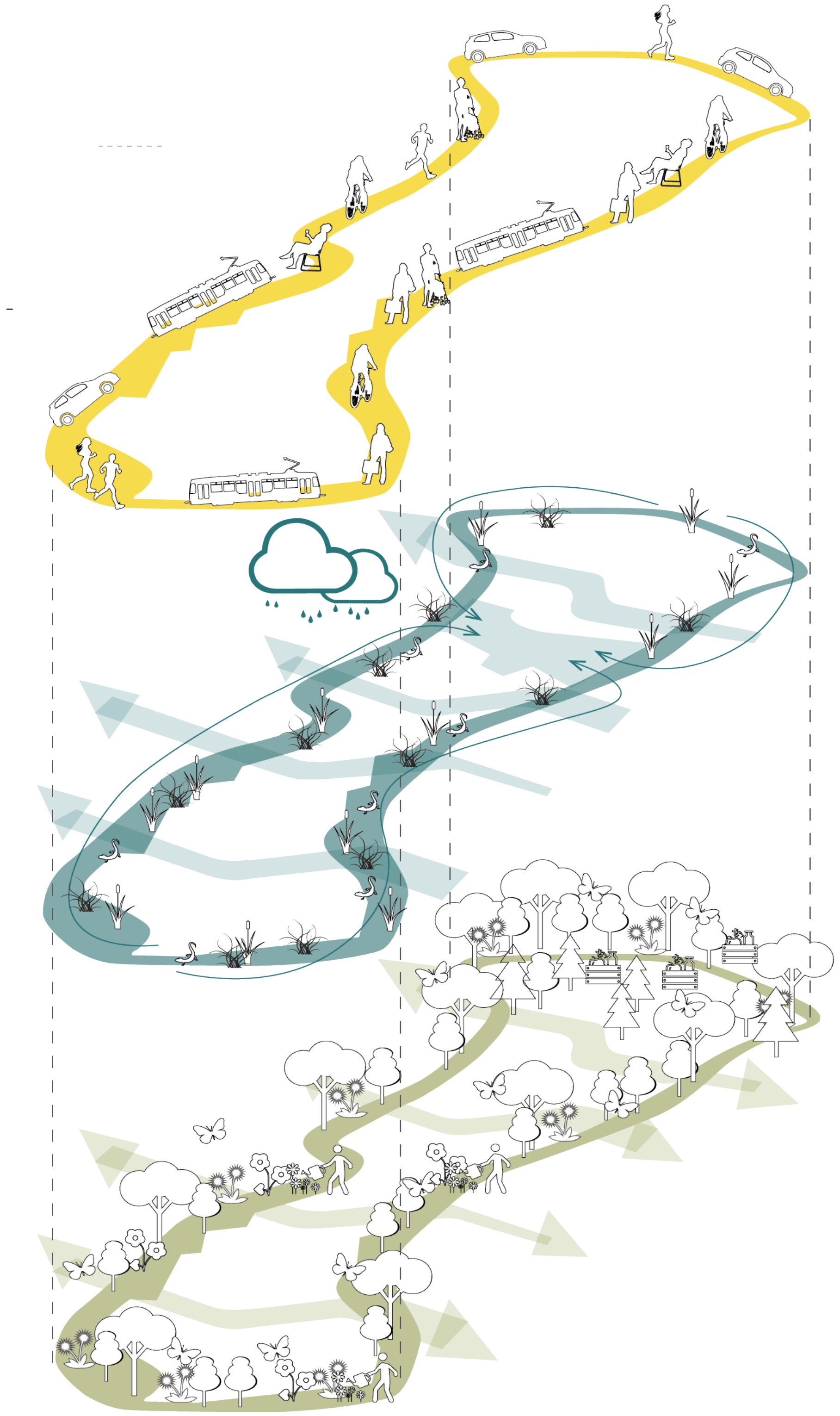
Green finger masterplan
(out of scale)
(© Ramboll Studio Dreiseitl)



Green finger section (out of scale)
(© Ramboll Studio Dreiseitl)

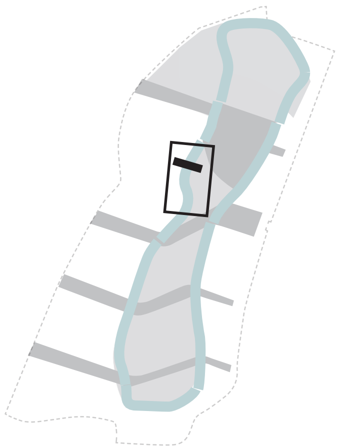
3.6.3 Parkway

The Parkway is the panoramic road that provides a loop connection to the entire area. As the street section shows, this infrastructure is planned to be the primary transport corridor of the new district. On both sides, there are large sidewalks for pedestrian movement. They are designed to be a pleasant area to encourage people to walk when they have to cover short distances. On one side there is a bike lane that aims to be the main transport infrastructure for the movements inside the district. The central part of the Parkway is occupied by the car and tram line. The new tram connection is an extension of the current line that can permit a fast connection with the city center of Heidelberg. In this way, the use of the car is left only for the travel outside the district that cannot be covered by the public transport system.
The road is designed to be a nice boulevard. Several lines of trees can absorb the water coming from the street during the rainy days and help to regulate the microclimate during sunny days thanks to the evaporation process. A relevant part of the Parkway section is occupied by infiltration areas that permit to the new PHV to be climate adaptive. The WSUD elements have a connection role because they have to collect the water from the green finger and transport it to the central lake. Swales and canals are implemented and inside them, several species of vegetation recreate biotopes that become ecological connections for different species of animals. Around the swales, some hills are developed in order to protect the sidewalks, the tram, and the car lines in case of intense stormwater events. These hills also promote a variegate urban landscape that can be used by the population as a recreation area.
In conclusion, it is understandable that the entire Parkway is planned to promote sustainable transport connections. The design of the road minimizes the negative influence of car traffic, giving priority to pedestrians and cyclists.

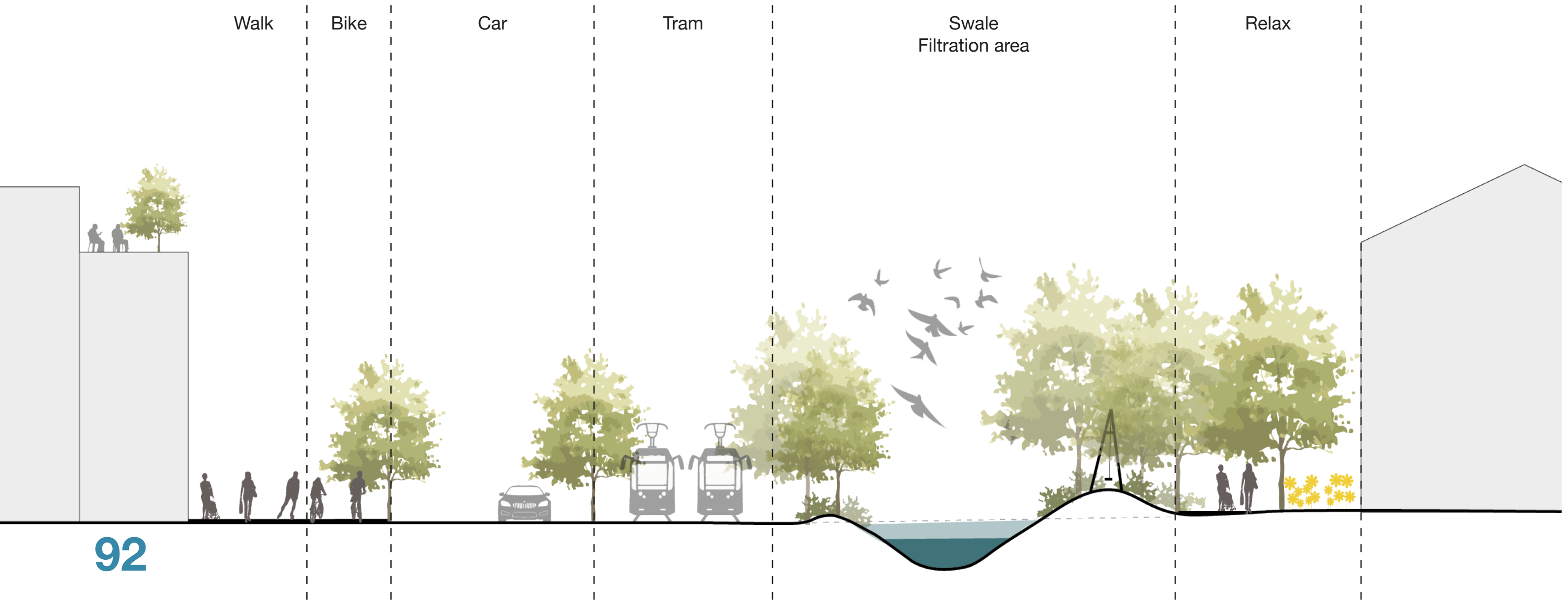


Parkway layer analysis
(© Author)

Parkway masterplan (out of scale)
(© Ramboll Studio Dreiseitl)



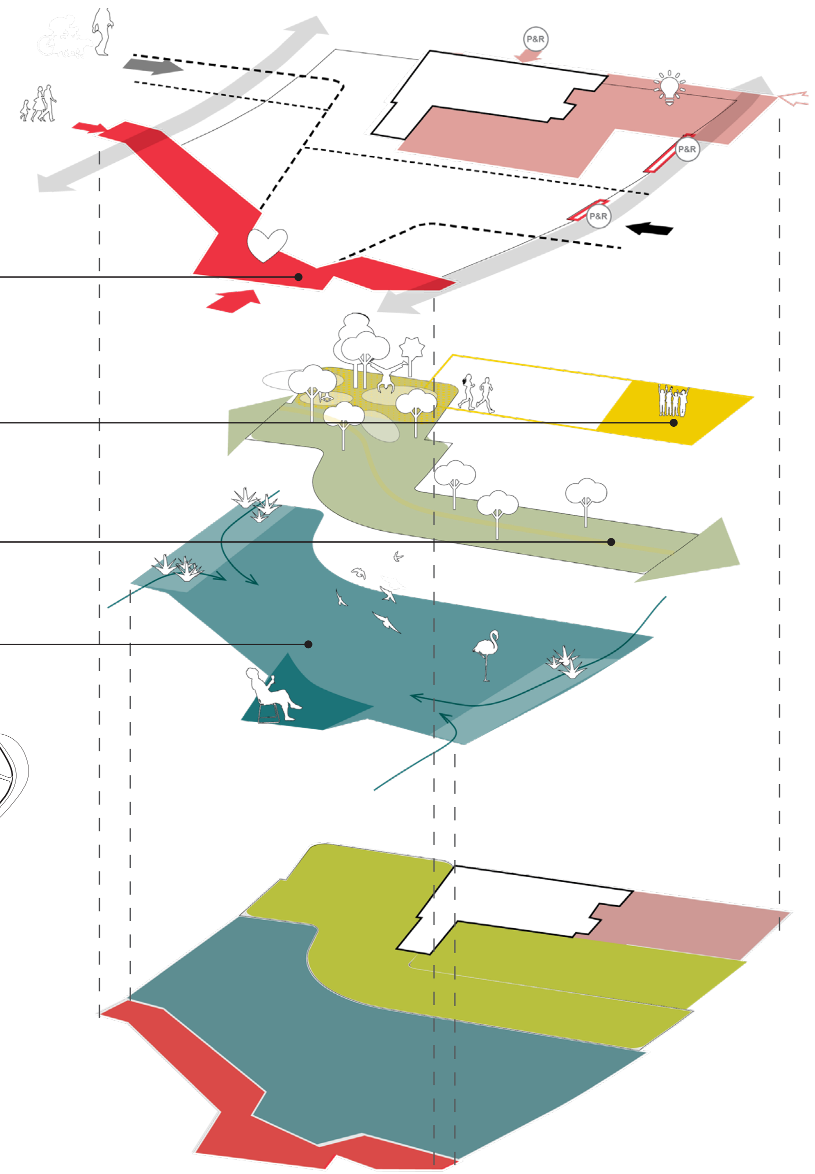
Parkway section (out of scale)
(© Author; based on Ramboll Studio Dreiseitl)

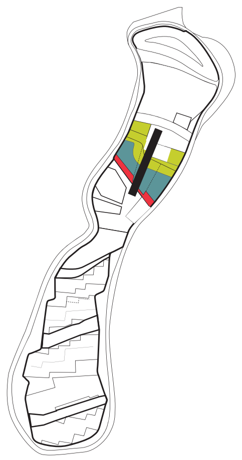


3.6.4 Central lake

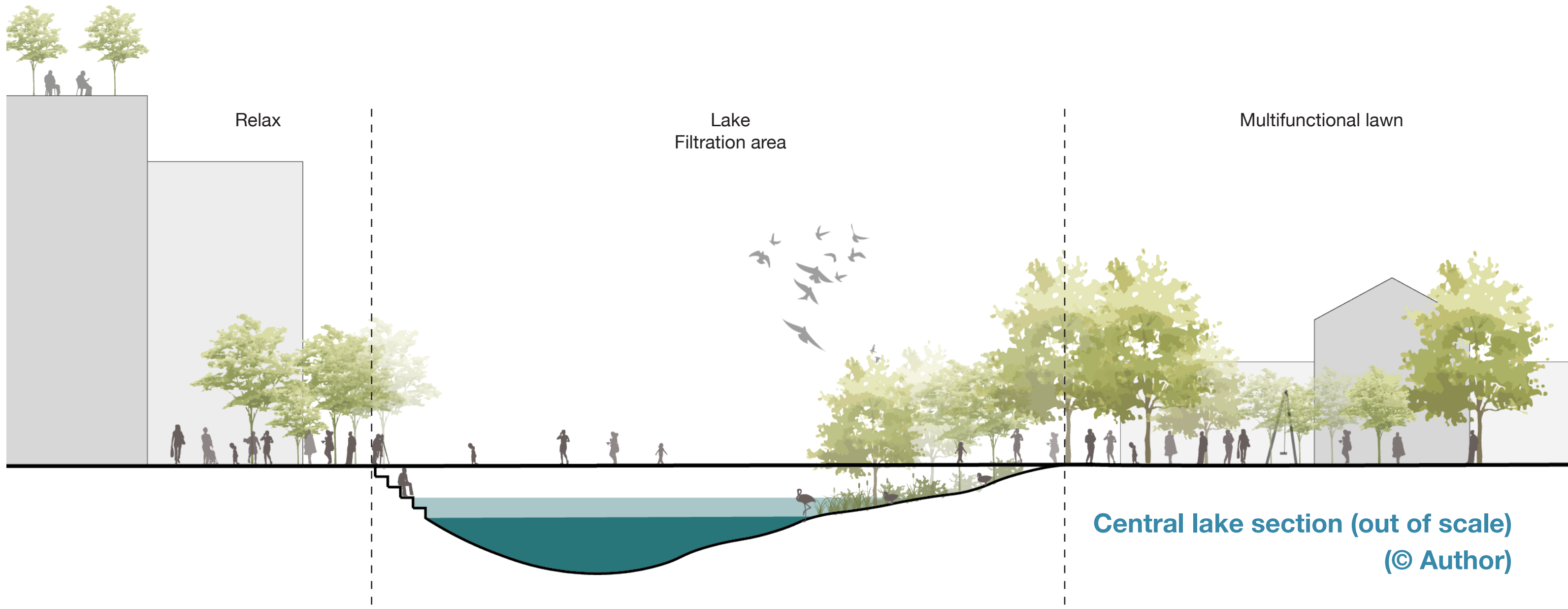
The central lake with the plaza and the central park is considered the heart of PHVision project. The preservation of some existing buildings, like the church and the barracks, creates a connection with the history of the district.
The center of the district is organized in areas that have different functions. In the northern part, there is the cultural building surrounded by a multifunctional lawn that can be used for recreation, public events, and sports. This area is directly connected with one of the green fingers that completely crosses the central area and create an ecological connection with the green outside the district. From the finger, there is a degradation of the green into the lake where the rainwater from the entire district is collected. In the south of the lake, there is the promenade where the inhabitants can enjoy the lake. Finally, the promenade is directly connected with the Seeplatz, which is a square overlooking the lake.
The central lake is designed to improve the quality of the district and it represents a landmark for the future settlement. The lake can be considered as a big detention point that combines several functions like recreation, water management, and biotopes quality. The design of this area permits the resident to entered directly in contact with the water. In the northern part, there is a degradation of the ground into the lake where the water is not deep, and dense vegetation of aquatic plants provides a natural feeling of the environment. The aim of this high quantity of green is to the green is to filter the water and become the habitat for several species of aquatic animals. The dimension of the lake is relevant, around 1,9 hectares. The area where the water is deeper has a dimension of 1,2 hectares while the area where the water is lower and where there are the plants for the filtration has a dimension of 0,7 hectares.
The water cannot remain more than three days into the lake otherwise it will become stagnant. For this reason, there is a system that catches the water from the deeper part and transports it in a filtration area where the water is cleaned using several biotopes and finally reemitted into the lake. During the rainy days, the recharge of the lake is possible thanks to the rainwater that is filtered before entering into the lake. In dry periods, the lake can be recharged thanks to an underground cistern where rainwater is collected. In case of severe drought, the water can be withdrawn from the aquifers through existing wells.

Central lake layer analysis
(© Ramboll Studio Dreiseitl)





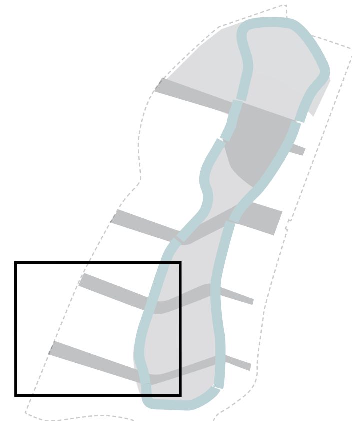
Central lake masterplan (out of scale)
(© Ramboll Studio Dreiseitl)

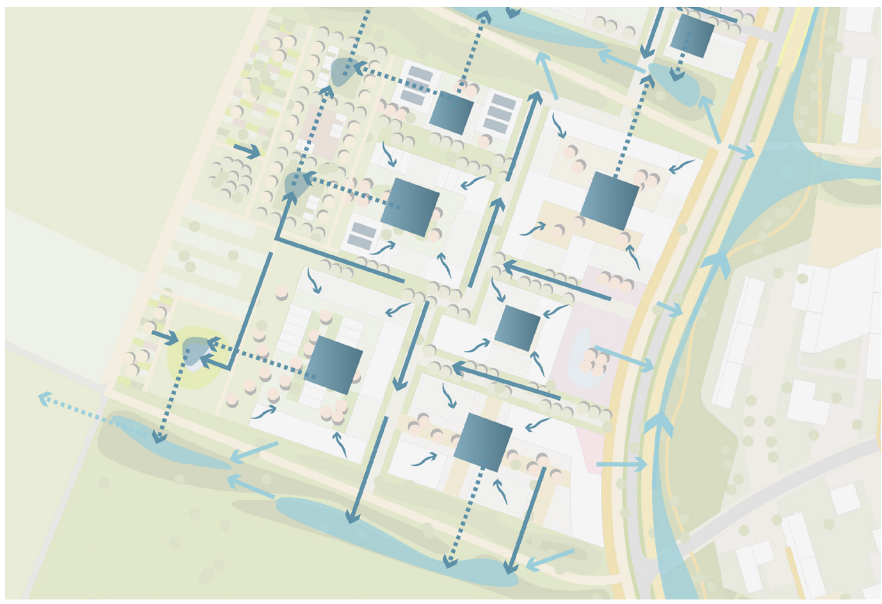


Central lake section (out of scale)
(© Author)

3.6.5 Block unit

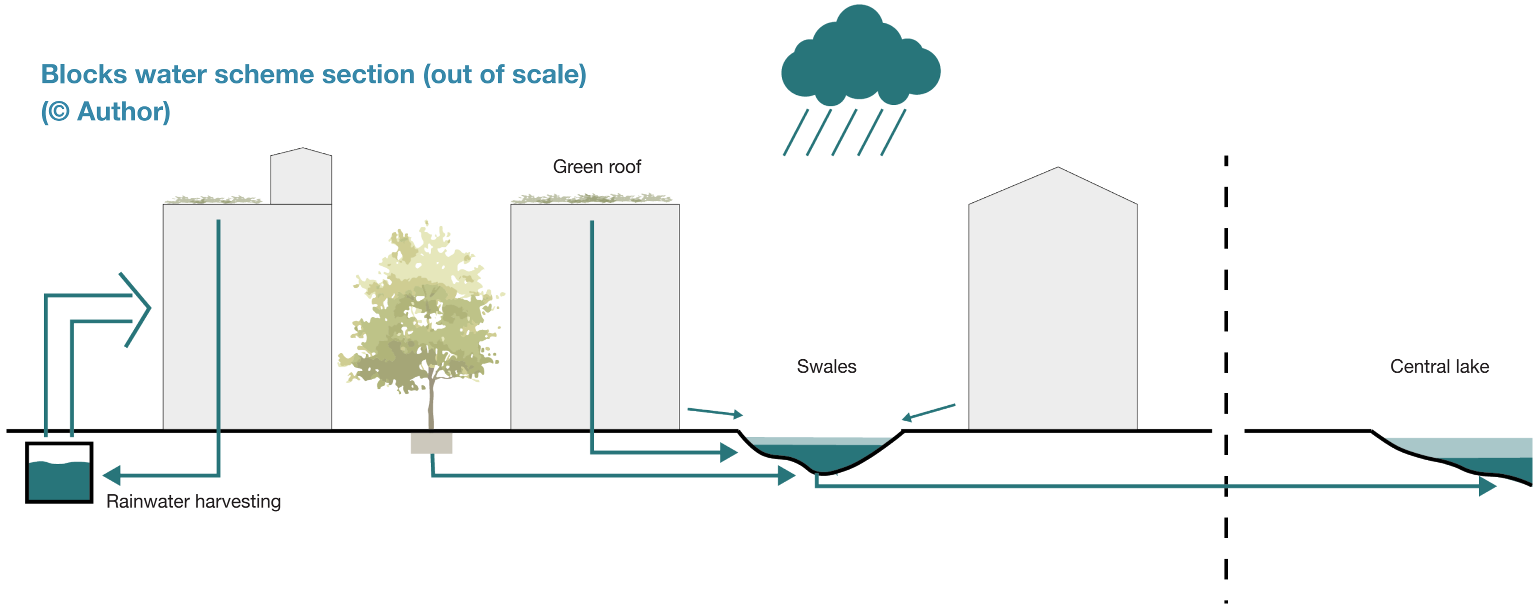
The blocks are part of a water management system that works together with the swales and channels of the green fingers and the Parkway.
The buildings are the first element that plays a role in the water management system. Many of them are equipped with green roofs that retain part of the rainwater while the exceeding quantity is discharged to the ground in water collectors. These collectors can be visible like rain gardens that filter the water or underground rainwater harvesting. The collected water can be reused in the buildings for flushing toilets.
From the collectors, the water can infiltrate into the ground but in case of extreme events, the exceeding quantity is discharged in the swales system composed by the green fingers. Form the green fingers the water can be discharged in the surrounding countryside or slowly transported in the direction of the lake.
The entire water management system of the district is developed in order to be able to retain as much quantity of water as possible in the site. Just in case of emergency, when also the flooding areas are covered by water, the exceeding quantity of water can be discharged into the sewer system maintaining the districts safe.





Blocks water scheme (out of scale)
(© Ramboll Studio Dreiseitl)

Blocks water scheme section (out of scale)
(© Author)



3.7 Discussion

From the research presented in this section, it is possible to state that the project for the new PHV area can represent an interesting case study for the implementation of the WSUD concept. In the first chapter was explained that WSUD involved measures at different scales, something that is fundamental for the PHVision project.
The first step is the regional planning level to define how topographical conditions can influence the project. In the case of Heidelberg, the hills on the west part of the city represent a relevant source of fresh air that goes down through the green fingers. For this reason, the fingers have an east-west orientation to permit the natural airflow. Moving down to the district and block level, the interaction with the different elements shown in section 3.6.5 by the "Block water scheme section" permit a virtuous water management system.
From the analysis developed in this chapter, it is understandable that the projects of PHVision can overcome the problem of the conventional stormwater management systems. The reduction of groundwater infiltration due to the high quantity of impermeable surfaces is something that does not concern this project. Green infrastructures are spread in the whole district and with their dense vegetation can filtrate the water that will contribute to the groundwater recharge.
Another problem of the conventional water management systems is that they can exacerbate flood conditions during periods of heavy rain. To solve this problem the high quantity of green has the role to reduce the runoff and maintain the natural water cycle into the urban area. Several detention points are distributed along the entire district to collect the water when the vegetation is not able to infiltrate into the ground the total quantity of rain. Just in case of emergency the exceeding water will be discharged into the sewer system.
The third characteristic of the conventional stormwater management systems is the incapacity to adapt to uncertain conditions due to climate change. From the analysis made in the chapter related to the blue infrastructures, climate adaptation is one of the project's milestones. Several analyses were done by the planners to calculate the amount of water that could flood in the area in order to make the district safe in case of heavy rain. The last scheme of section 3.6.1 shows that these areas are located along with the main green infrastructure of the district. Swales and detention areas will be implemented following as WSUD elements to make the new neighborhood a sponge district.

The attention will move now to the answer of the second research sub-question:
Are there some suggestions that are possible to implement in PHVision based on the experiences of the selected European examples and the implementation of WSUD?
From the analysis presented in this chapter, it understandable that PHVision is a project that once will be developed could become an interesting case study with the same relevance of the examples presented in chapter two. Previously was explained that this project is part of IBA Heidelberg and for this reason, several German and international experts worked on this project ensuring a high quality of the work.
Considering the learning outcomes of chapter two, it is possible to state that the "high retention capacity", the "green roof and green façades role" and the "water treatment ability" are something that PHVision already takes into consideration. Possible suggestions for the future development steps of PHVision can be found in citizen involvement, a key element in all the European examples. The PHV area is currently unused and for this reason, there are not inhabitants that can be involved in the process. However, the new district will be implemented with many research centers, university activities, factories, industry 4.0, etc. The employ of the societies that will move to the new area and the students of Heidelberg university can be involved in workshops or focus groups to decide how the new outdoor areas of the PHV should look like. Their involvement is fundamental because one of the three main reasons that make still uncommon the use of WSUD Lack of knowledge, acceptance, and awareness. The inhabitants and the stockholders involved in the transformations are not conscious of sustainable water management advantages. The use of WSUD is "appealing as long as the space is usable and safe" (Hoyer et al., 2011). Unsafe feelings emerged during the project development of Water square Benthemplein. The inhabitants were worried that the area could be unsafe in case of heavy rain, so the dangerous parts were marked with colors. A similar approach can be implemented in the new PHV. Information panels should show the importance of having good environmental quality and can also give information regarding the behavior to be followed in case of flooding.

Chapter 4

Discussions and conclusions

4.1 Discussions

In this final chapter, the findings of the European examples and case study analysis are going to be discussed in connection with the theoretical chapter. This final discussion aims to answer the research question of this master thesis that is:

How does Water Sensitive Urban Design change the integration of water in urban planning from waste to design element?

The need to reduce the stagnant water during the 19th century was the reason that promoted the development of conventional stormwater management systems. The cholera epidemics that happened in the slums of the industrial cities were the reasons that pushed the planners to consider the rainwater as a waste element. For this reason, the impermeabilization of city surfaces was promoted to have a high and fast runoff into the sewers system.

In the northern regions where the chosen examples are situated, an increase of rain from 10% to 40% happened from the beginning of the 20th century and in entire Europe, an increase of stormwater event is occurring (EEA, 2008). The conventional stormwater management systems introduced in the 19th century, are not adaptable to manage the high quantity of water that falls to the ground in a short amount of time. The new approach of WSUD has the aim to better manage the stormwater overcoming the idea to consider the water just a waste element.

Thanks to the analysis of chapters two and three, the research question is answered by considering the water as a multifunctional resource. While in conventional drainage approaches the stormwater is considered as a nuisance to be removed from the urban area as quickly as possible, in WSUD the public spaces are redesigned to retain the water into the site giving the possibility to use it in new ways.

In Augustenborg the park's lake, the fountains and the canals that collect the district water are newly designed elements that improve the quality of the public spaces. In ZoHo and San Kjeld, the rain gardens and the detention points represent a green area that can flood in case of intense rain events. In this way, the water changes the landscape of the public spaces becoming also a recreational element for kids or biotopes for different animal species. Hence, the introduction of these green elements permits to reduce the water runoff, one of the main goals of WSUD listed in section 1.4.1. An essential goal is also to make the retained water clean. In order to do that several species of vegetation are used for the filtration.

Another innovative approach of integrate the water in urban planning as a design element is water square Benthemplein. Before the redevelopment of the square, the water was collected by the sewage system and discharged into the nearby canal. The purpose of manage batter the water pushed the planner to redesign every element of the square. The plaza was reorganized with the construction of three retention basins that collate the water from the surrounding buildings. When there is rain, the water is used as a multifunctional resource. It became a play element for the kids, but it is also collected in an underground storage basin to be filtered and reused for the irrigation of the green or in the building's toilets.

Probably the case study of PHVision shows the maximum potential to use the water as a design element using the principles of WSUD. The green fingers have the aim to collect the rain that comes from the district's blocks. The visible water promotes an active evaporation process that increases the production of fresh air making the green fingers leisure places for the residents. The central lake is planned to be the landmark of the new district. The aim is to make it the hearth of PHVision since the main activities of the district are all developed around the lake. The central area wants to be a recreation point for people that live and work in the neighborhood and for this reason the lake is designed in order to give different experiences and enjoy the free time. The northern part is greener, and people can explore a wild nature. The southern part has an urban feeling with a pleasant promenade and several steps that permit people to enter in contact with the water. The lake does not have only an aesthetic function but is the final element of a complex water management system that aims to reduce the drainage infrastructure and the related development cost, a fundamental goal of the WSUD (The Urban Stormwater Best Practice Environmental Management Guidelines 1999).

Design with water it means also citizen participation. The correct involvement of the inhabitants can contribute to improve the design quality of the project and overcome one of the main problems that still make not common the use of WSUD: the lack of knowledge, acceptance, and awareness (Hoyer et al., 2011). Even if there were some relationship problems with the citizens, their involvement in Ekostaden Augustenborg permits to improve the aesthetic value of the projects. The kids were involved in the design of the new kindergarten courtyard developing several water playgrounds while the carpenter of the districts built several WSUD elements now used in the district. In the project of water square Benthemplein, the citizen participation permits were useful to understand their concerns and make the future square safer. This approach should be used with the future inhabitant of PHVsion, following the suggestion developed at the end of chapter 3, to explain the importance of integrating water in urban planning as a design element.

The introduction explained that this research does not consider economic aspects.
The analysis criteria do not take into account the costs because the topic of this research is to understand how the water can be considered a design element in WSUD. The costs are a fundamental topic for the implementation of this concept and some discussions about it are necessary for this final part of the master thesis.
With the increase of extreme water events, multi-billion dollar disasters are becoming more common (IPCC, 2012). Unfortunately, the literature on the socio-economic impacts of disasters is thin and the data are limited (Allaire, 2018). When floods occur, there are two types of costs: "tangible" (financial) and "intangible" (non-financial) cost. Engineering studies consider "tangible costs to include damages to buildings and contents as well as business interruptions that can be expressed in financial terms. Meanwhile, 'intangible' costs would include health, environment, and any cost measured in terms of the opportunity cost of time" (Allaire, 2018).
Calculate the costs of the disaster is not simple. The full economic value of a disaster would consider the change in social welfare attributable to the event. A problem is that many econometric studies simply compare GDP before and after a disaster (Hughes & Hsiang, 2013), but wider attention to the socio-economic aspects of disasters is needed. The UN, with the Sendai Framework for Disaster Risk Reduction aims to reduce by 2030 a broad variety of disaster impacts including mortality, affected people, economic loss, and disruption of basic services. In addition to the Sendai Framework, other regional and national entities are recognizing the importance of reducing flood impacts, including the E.U.
When a flood occurs, there is not only the problem to understand which are the socio-economical cost of the event, but someone must also compensate the private individuals for the damages received. Recent studies found that most people do not know if they are living in areas that can flood and, if they do, many do not take measures to protect themselves against flooding (Khan, 2018). They also do not know that many home insurance policies do not cover water damage from flooding, but only damage from broken pipes or similar issues. Even the government has the responsibility to compensate for the damages, but it can also refuse to pay house owners if they could have implemented insurance add-ons that do cover flood damage (Khan, 2018).
The implementation of WSUD can solve flooding problems but it necessary to evaluate the 'return' time that is required to make the investment profitable. WSUD is still not commonly used because the conventional systems are cheaper. The construction of centralized stormwater management systems permits to have efficient costs for construction and maintenance. At the same time, the implementation of impermeable surfaces required less money compared to the implementation of permeable green areas (CRC, 2016).
Despite this, in the theory of chapter one was explained how conventional water management systems are not able to adapt in case of climate change. For example, the big flooding event that happens in the city of Copenhagen in 2011 caused damages for more than 800 million euros. Decentralized stormwater management systems, such as the application of WSUD, can help in saving maintenance and emergency costs. Considering the long-term costs, the use of WSUD promotes several benefits. For example, it is not necessary to spend more on the upgrade of the sewer system to face the future increase of rainwater because the water can be collected on the site. At the same time, it is not necessary to develop new sewerage treatment infrastructure because the green can cover this role (CRC, 2016).
Considering again the example of Copenhagen, the cost of installing new drains systems is estimated to be between 1,5 and 2,4 billion euros. Just the cost for the construction of decentralized water

management elements is estimated to be around 750 million euros. The expert calculated that without action, damage to buildings and infrastructure, combined with lost earnings from storm surges and floods, could be estimated in more than 3 billion euros. From the analysis of the data, it is immediately understandable that in a long time the investments are profitable. What makes not common the implementation of WSUD is that its adoption in practice continues to be influenced by the outcomes of economic evaluations that focus on the direct implementation costs of WSUD (CRC, 2016). The problem is that some damages, due to flooding conditions, are difficult to estimate (such as household-level losses) and, on the other hand, some benefits related to the implementation of WSUD that have not monetary valuation (such as the increase in urban landscape aesthetic). This is an issue if we want to make out cities more livable, sustainable, and water sensitive.

4.2 Conclusions

The foundation of this work is the recognition that the severity of stormwater events cannot be overstated. With climate change and the increase in extreme weather events, the cities need to reinvent themselves to be able to face these future challenges.
Through the literature review, this analysis highlighted the limits of the traditional water management systems based on high impermeabilized surfaces and underground sewers. The analysis of some European projects demonstrates that WSUD could be a valuable approach to face climate change through the reintroduction of a high quantity of natural elements into the cities. Answering to the research question was also clear how the water can improve the aesthetic value of the project area.
Despite these positive outcomes on the quality of the WSUD approach, further cross-disciplinary research and analysis need to be developed in cities that implemented WSUD tools. The goal is to improve the understanding of the dynamics that characterized these projects and try to identify relevant and viable water management strategies that cities can implement to simply overcome the problems of the traditional ways to manage rainwater.

From the analysis developed in this master thesis, it is understandable that a relevant point in the implementation of WSUD is the acceptance and the awareness that the citizen and the stakeholders need to acquire about the concept. WSUD is not only related to civil engineering like the conventional stormwater management approach, but it involved a variety of disciplines such as architecture, design planning, ecology, etc. This characteristic is essential for the quality of the interventions, but a good project is not enough without citizen awareness. The communication system needs to cover a central role in the development process because the inhabitants need to learn the importance of the WSUD approach. Local inhabitants are not aware of the problems connected with rainwater management and the advantages of decentralized solutions. Generally, they are not well informed about the issues of climate change and how it is complicated to manage the water with a conventional stormwater system. They need to feel safe and understand the importance of sustainable stormwater management systems. The projects analyzed demonstrated that if the communication is considered, WSUD can generate interest in the citizen that appreciate the quality of visible water and green infrastructure as design elements of the public spaces.
At the same time, more deepened researches related to the cost of implementing WSUD are necessary. In the discussion was explained that until now the main researches just take into account the direct implementation costs. However, also the non-monetary benefits need to be analyzed to have a complete overview and provide good reasons related to the importance of implementing WSUD.
Finally, further researches could be developed to understand how WSUD can be implemented in European countries that have different planning laws. In this master thesis was understandable that WSUD is a flexible concept that can be implemented both in existing urban structure and in new projects. This flexibility can be a reason to push the public authorities to use more this concept but deepen analysis should be done to understand how WSUD can be integrated into different planning contexts.

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