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Integrated urban design and open storm drainage in our urban environments: merging drainage techniques into our city's urban spaces

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Abstract

Flooding is the most common natural hazard in Europe. Cities cannot rely only on underground solutions which are expensive and inflexible. In order to reduce the negative impacts of flood, open and surface solutions play a key role in the efficiency of urban drainage systems. Utilizing the earth's surface as part of sustainable water infrastructure, also as powerful element for creating the space, adds multiple values to our urban environments. This article suggests a framework to increase the likelihood of turning the idea of flood resilient city to a best practice. The paper is clarifying the design principles. The target is turning a space to a functional place by applying drainage techniques in urban design, which requires robust local integration between the urban space and technical solutions. The study of storm water management in the Swedish and Dutch contexts was an important base for this formulation. Considering the important share of urban design in urban transition success, the paper is focusing on categorizing the required steps of flood resilient urban design.

Key words: adaptive urban landscape, blue green infrastructure, ecological urbanism, sustainable drainage systems, urban design principles, water sensitive urban design

INTRODUCTION

In 2050 around 67% of the world's population will live in the cities according to the United Nations projection. Such urbanization has usually negative impacts on the hydrology and water quality (Qin *et al.* 2013). The human health is in danger as well as ecosystems of the large number of cities due to emission of contaminants and nutrients (Finotti *et al.* 2014). The climate is changing and is expected to get even more unpredictable and intense. However, the level of vulnerability to climate extremes will determine the severity of impacts (IPCC 2012). In the year 2014, almost 54% of the world population resided in cities (UN 2014). 15% of the world population, mainly urban population, is predicted to be at risk of being flooded from sea level rise and river discharge (Ligtvoet *et al.* 2014). The combination of rapid urbanization and climate change results in more flood issues, water scarcity and water pollution (Van Leeuwen 2013). Due to the global warming, severity of extreme rainfalls will increase (Jongman *et al.* 2014). While the bulk of cities' storm water drainage has been designed in the absence of collaboration and trans-scale ways of thinking, more dynamic systems should be devised. It is necessary for the government to introduce the planning strategies and highlight water challenges in all scales of planning. Sustainable urban water management is the key to success and is based on integration of urban planning and urban water cycle management (Wong *et al.* 2013). Sustainable planning is only achieved through combination of top-down and bottom-up approaches and it is different from city to city. Considering the climate

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changes impacts, the management methods usually encourage the cities to start moving towards ecological urbanism and emphasize the role of planning models in urban sustainability (Mostafavi 2010). In such approaches it is not only the water flow that is a driver for ecological urbanism but also the other way around. There is no denying importance of urban water governance. However, the emphasis in this article is on planning and design of flood resilient cities in which storm water challenges turn to assets and not threats.

HOW TO APPLY URBAN PLANNING

Transforming the existing cities into water resilient ones requires both site-level and district-level strategies. It would be beneficial if the planning goals get incepted in the early stages, thus helping to ensure synergy between urban drainage solutions and urban development goals (Fryd *et al.* 2010). There are multiples of urban planning objectives, but some should be highlighted more such as protecting the city from rivers and sea, getting ready for both water scarcity and extreme rainfalls, making the water features accessible and safe, increasing the awareness of the inhabitants and involving them, improving urban environments by adding more attractiveness and comfort to the public urban areas and private lands and last but not least developing social, ecological and economic values.

Synergy is vital in structuring different planning levels. In Regional planning the key elements and urban infrastructures are placed and designed in larger areas than a single city and it involves physical and spatial planning. In land-use planning, the function of land is chosen individually and in symbiosis with surrounding functions. Land-use planning presents visions for further developments in any planning area or site, district and city. However, the planning terms are sometimes used interchangeably (Evans 2004).

Urban projects ought to be connected and work together at the site level also with the comprehensive plan. Furthermore, developing the connecting methods in the detailed plan of the catchment area is essential. There are still discussions on how to make an explicit framework to such integration. Questions such as to what extend the comprehensive plan should be affected by the drainage methods, how to address the drainage techniques in urban design or what kinds of detailed plan and permit are required. The fact is that time matters and although achieving a waterproof city is a long-term process, it is necessary to rethink our urban developments and make it more water sensitive. No matter how big the measure is, every drop counts. Water and urban planning integration is a crucial step to flood resiliency. In addition to amending the design and technical aspects of urban water infrastructure it improves the quality of urban environments. Climate change impacts should be understood and addressed in urban development plans. All aspects of different layers of urban infrastructure need to work together. Solutions occur through the combination of art, design and technology (Mottaghi *et al.* 2015).

EUROPEAN CITIES AND THE FLOOD CHALLENGES

There are trends and pressures, cities undergo. Nevertheless, they need to sustain and survive economically, socially and environmentally and rapidly get back to the qualified life condition (Mori & Yamashita 2015). Climate change is one of the most serious issues threatening the human being and different aspects of its life. Cities need to be protected against flooding but also water scarcity and heat risk while ensuring water quality. In Europe floods turn to a serious problem. Between the year 2000 and 2012, the average of floods cost was 4.9 billion Euro a year which is predicted to increase five times and reach to 23.5 billion by the year 2050 (Jongman *et al.* 2014).

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Water has always been a vital resource to human beings. The first civilizations have appeared on the locations which are close to water bodies and if the water is accessible then the civilization can thrive. The structure of water bodies had a major impact on the shape of the cities. Eventually, due to the human needs, different networks for water transportation, irrigation, drinking water and wastewater were developed and urban water infrastructure is still evolving. However, water related risks bring further urban development trends that changes urban planning priorities. The role of water challenges is getting more extensive in the development process of European cities. Water became more crucial element, rather than just an attraction. In the Northern Europe, tackling water challenges is slightly turning its focal point of planning to the three points below:

- The spatial and economical values which refer to the ways that water have been used over the centuries for adding qualities to human life. The emphasis here is on all the potentials water brings the city including water transportation, edges, attractions etc.
- Robustness against sea-level rise and river discharge
- Resilience to storm water and surface runoff

However compared to the first two, the third concern has recently been drawing the cities attention since cities are less experienced in how to deal with runoff. For instance most of the Dutch cities, as a result of geographically being part of a low Delta and a very flat country, have been dealing with flooding over the centuries. Ever since the origins of the Dutch cities, water has always been playing a critical role in shaping those cities history and structures. In some parts of the country the cities are exposed to threats from four different sources, the sea (outside), the rivers (inside), precipitation (above) and ground water (below). When it comes to floods from the discharges of the rivers or sea level rise, National government, under the Delta program, is responsible to protect the cities from flooding. Nevertheless, the cities need to protect themselves against extreme rainfalls. Cities like Rotterdam, Amsterdam and Dordrecht all have different strategies and apply different approaches in this matter. They try to cooperate and combine their own experiences with others but find solutions locally (Mottaghi 2015a). There are different sustainable solutions developed as storm water management techniques, which are known under different titles, LID, SUDS, WSUD, BMPs, etc. Such systems are not only bringing benefits to urban water systems, but also bring benefits to urban areas through functional synergies (Fryd *et al.* 2010). Understanding the magical role of urban planning and design and applying them in an appropriate way, improves the storm water management systems and increases their effectiveness. The two critical steps are separation and retention of storm water. Unfortunately at the moment the major drainage system of cities around the world is still the combined system in which both the sewer and the surface run-off are collected in the same pipe system. Thus, more frequent overflow of the sewer system is as a direct consequence of extreme rainfalls and floods (Abdellatif *et al.* 2014). Existing infrastructures need to be revised and it requires fundamental decisions. Drainage systems evolution should be towards a higher living standard, biodiversity and less environmental impacts (Grant *et al.* 2012). Nevertheless, making urban areas resilient does not only mean to plan for the higher sea level, rainfalls and river discharges. Considering the heat island effect, the planning for the possible drought periods in future is also of the crucial importance.

After facing extreme floods and being affected by the huge impacts, some cities are promoting solutions to reduce damages in the future. Cities such as Rotterdam, Amsterdam, Copenhagen and New York started to apply methods such as retention increase through surface solutions or surplus water discharge speedup and leading it to less vulnerable areas (Van Leeuwen *et al.* 2015). Integrating the drainage techniques with urban open spaces such as public squares, parks and green spaces, improves other aspects of the environment, rather than only the technical and aesthetic aspects. Multi-functionality turns to one of the main principles of design. Integration of function, patterns and values, results in biologically enriched ecosystems as well as services for human beings. We

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not only need to understand the way water catchment areas work and connect together, but also understanding the green infrastructure is required. Furthermore it is necessary to have a comprehensive knowledge of the residents' needs and cities' existing land use and physical plans (Mottaghi *et al.* 2015).

In all storm water management techniques, various sectors such as energy, health and transport, are involved in providing principles for sustainable development strategies and functions as a part of integrated water cycle management (Langford & Briscoe 2011). Adaptation measures require multifunctional adaptation strategies and cannot be implemented as single-purpose strategies (Buuren *et al.* 2013).

DESIGN APPROACHES AND CONCERNS

The urban design approaches usually consist of frameworks and strategies. At the end the design should be able to suggest new ideas for area-specific implementations. Accordingly, it is important to make the adaptation strategies clear in advance. The basic strategies can roughly be divided into the categories below:

- *Increasing the robustness of our systems* entailing the maintenance and strengthening of our storm water systems
- *Adapting our urban spaces to the climate changes*, which means to make them more flexible and innovative, through solutions addressing all urban environmental aspects, including flood resiliency
- *Collaboration*, which is not only about cooperating with other parties, but connecting different urban projects and addressing adaptive measures to other spatial development projects.
- *Creating added values*, it will be only achieved through an appropriate integrated design of urban drainage systems and urban environments (Rotterdam Climate initiative 2013).

The influence of the share of urban surfaces in protecting the city from urban drainage flooding is not deniable. Protection of existing vegetation and water bodies and increasing their presence within the city borders are some of the solutions to the reduction of the flood impacts. More paved and impermeable surfaces and lack of urban greenery, add more vulnerability to the drainage infrastructure and ends to more damages caused by flooding (Shuster *et al.* 2005). Lack of greenery also brings the cities the urban heat island effect which is about the increase of heat waves (Gill *et al.* 2007). Water sensitive urban design solutions produce the synergetic effect when applied to urban infrastructures. The goal is adapting the city to the climate change and mitigating the negative impacts. In terms of dealing with floods, solutions are aiming to decrease and slow down the runoff, increase infiltration and evapotranspiration. In addition to climate adaptation, heat alleviation, improved biodiversity, food production, improved air quality, energy production (from biomass and water) and social improvement are other targets of such adaptive measures (Potz & Bleuze 2012).

There are required material, such as fundamental analyses and various kinds of modeling, to be used as the base for planning. For instance, there are some areas in each city which usually are exposed more frequently to different types of flooding. Runoff models show the rainfall conversion to runoff and specify the problematic places and the need of retrofits for adaptation to the extreme events. Although such models are, to some extent, unrealistic and with inaccurate magnitude, it gives ideas of what might happen in the future and reveals sets of goals and objectives. To give an example, after the Sven storm which hit the city of Malmo in Sweden in 2013, in which the water rose almost two meters, one run-off modeling was provided by the municipality. In this model, Malmo is imagined to undergo the same rain event as Copenhagen went through in July 2011 (with the precipitation of 150 mm in two hours). The model showed that the flow will be mostly on streets, especially in central Malmo (Mottaghi 2015b). On the other hand, according to the

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comprehensive plan, it has been decided not to expand the city over the farmlands and instead to focus on inner-city densification. Since such densifications usually lead to thinning of the city greenery, it is crucial to focus on roofs, street edges and using the full potential of open and public spaces. Malmo recognized the efficiency of multifunctional design and the necessity for adjusting the streets in planning and the development process. Such analyses will be quite helpful in structuring the intended cloudburst plan and Malmo water plan, which Malmo has aiming for.

SUSTAINABLE URBAN DRAINAGE FACILITIES

Adaptive measures to pluvial flooding usually consist of the combination of ground level rainwater drainage solutions, thus creating a more pronounced blue green layer. The solutions usually comprise one or more mechanisms of storage, infiltration, treatment, transport and evaporation. According to Stahre (2008) the four groups of sustainable urban drainage are categorized as following. *Source control* is the small scale facilities which handle the storm water on the private lands. *Onsite control* is small scale facilities which handle the storm water in upper parts of the drainage systems on the public lands. *Slow transport* is systems which transport the storm water in drainage system. *Downstream control* is mainly applied for storm water temporary detention and includes large scale facilities that take place in the downstream parts of the system. Figure 1 shows examples of each category.

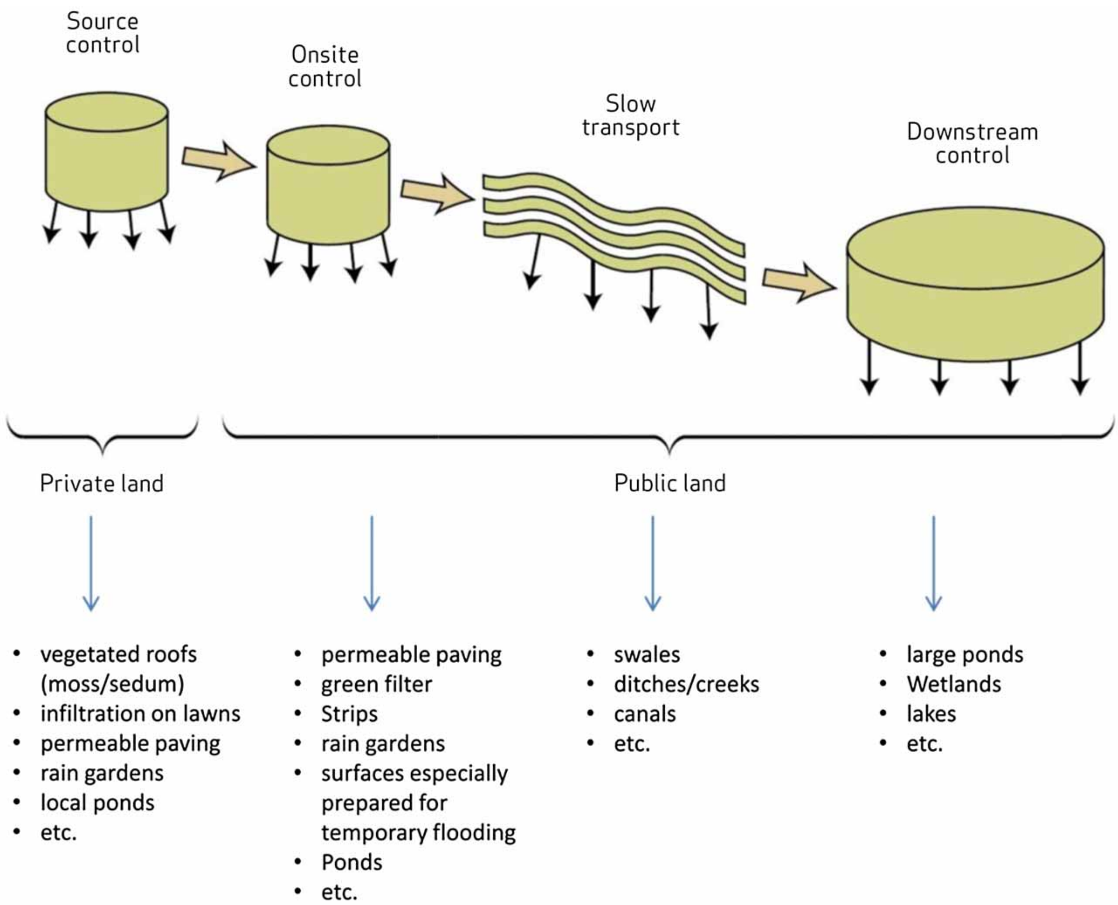

Figure 1 | Sustainable urban drainage facilities (Stahre 2008).

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THE KEY PARAMETERS FOR ECOLOGICAL DESIGN

Urban water management needs not only to provide the cities with rich water security, water quality, drinking water and sanitation, but also to be sustainable. Therefore, urban water infrastructure plays a key role. It is necessary to achieve the mentioned targets as well as bringing the cities more climate robustness, biodiversity and attractiveness. It requires a rich combination of spatial and physical planning, gained through good urban water governance. However, only rich and functional design can guarantee the efficiency of urban infrastructures. According to Backhaus & Fryd (2013) the five key parameters for sustainable drainage facilities are:

> '*Terrain changes*' - the necessity for deliberation of leveling, '*Water dynamics and dimensioning*' - the need for designers to have good dimensioning skills, '*Stormwater accentuation*' - the requirement of spotlighting water management as either the main design concept or the concept connected to other design concepts and functions, '*Construction and maintenance*' - the need for suggesting construction methods and maintenance solutions in advance in the design process, '*Site history and context*' - the prerequisite for understanding the site history and deep knowledge on the site context. However most of the above mentioned parameters are the important features in every piece of landscape design.

Sustainable drainage techniques are usually open surface solutions created by utilizing the urban landscapes (Figures 2–5). According to Yu (2012), Kongjin Yu 'espouses an approach to landscape design that celebrates the aesthetic of high-performing, low-cost, healthy feet'. He proposed the new aesthetic principles for ecological urbanism and its infrastructure. The principles allow more functioning, maintenance and gratitude of ecological urbanism. He calls it the 'Big Foot' aesthetic and tries to specify major principles of aesthetics and apply them as urban development approaches in his projects. Some applied principles are: *Making friends with floods* (The Floating Gardens of Yongning River Park), *Go productive* (The Rice Campus of Shenyang Architectural University), *Valuing the ordinary and recycling the existing* (Zhongshan Shipyard Park), *Let Nature Work* (The Adaptation Palettes of Tianjin Qiaoyuan), *Minimal intervention* (The Red Ribbon in Qinhuangdao City, Hebei Province) and *Land as a living system* (Shanghai 2010 Expo Houtan Park) (Yu 2011). 'Techniques such as adaptive urban landscaping or vegetated storm water treatment systems, including bio filters or rain gardens, green roofs and facades, wetlands, swales and so on are some samples of practical methods. Most of the techniques are about mimicking the nature as a resilient system.

Figure 2 | Rotterdam Watersquare Benthemplein. Designed by De Urbanisten. The photo is taken by Misagh Mottaghi.

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Figure 3 | Rotterdam Zuiderpark. Connecting the waterways. The photo is taken by Misagh Mottaghi.

Figure 4 | Storm water ecological techniques in Augustenborg Eco-City, Malmo. The photo is taken by Henrik Thorén.

Figure 5 | Amsterdam Polderdak Zuidas green roof. The photo is taken by Misagh Mottaghi.

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Creating natural topographies, pavements, using specific vegetation, etc. are some of the elements that enable the creation of attractive urban space' (Mottaghi *et al.* 2015).

CONCLUSION

Cities need to get prepared to deal with extreme water events. Although good urban water governance plays a key role to succeed a well-organized framework is needed to turn the idea to effective practice. Focal point of planning is required to be shifted towards water sensitivity. Climate change adaptation strategies should be clarified in advance and addressed in different phases of the planning process. Sustainable urban drainage facilities are required to be merged in urban design which provides the storm water infrastructure with more efficiency. Integrated urban design-based urban run-off management will strengthen the city blue-green infrastructure. However, only rich and functional design can guarantee the desirable result. Accordingly the key parameters of design are essential in the designing process and new aesthetic principles are necessary to be addressed in ecological infrastructure. The design principals should be driven towards functioning, maintenance and appreciation of ecological urbanism.

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